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LEGENDARY

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Zak Storey

3D PRINTING SPECIAL

THEY SAID: "Zak, you can't put '3D Printing Special' on the cover, that doesn't sound very interesting." Well, to heck with management, I'll type "3D Printing" where I darn well like.... Probably. (Please don't fire me, I love this job.) Yep, I have been inundated with people emailing in, asking me to get some more 3D printing content in the mag—namely, a primer and guide to this wonderful world. So, that's exactly what we've done. This issue, I've recruited one of our resident modders, Kris Butterill, to give you the low-down on all things 3D printing: Where we're at, what's available, and what you might want to invest in to get started. Then our other 3D printing expert, Dave Alcock, has done a fantastic DIY feature on how to build your own wacky ergonomic keyboard, complete with 3D-printed chassis, wiring diagrams, and programming guide to get your own funky board up and running. It's a unique project, but the basic principles can be applied to any keyboard design you like, and it certainly makes for an interesting read.

We're also looking at doing some follow-up content going forward; mostly just tutorials, and perhaps the odd printer review here and there. Nothing that's going to take over the mag in quite the same way as our flagship features this issue, but just enough to scratch that itch, and perhaps get you interested in what's undoubtedly the future of manufacturing.

But don't worry—we know this isn't *Maximum 3D*. If the world of resin models isn't your jam, I've made sure to get some juicy content in this issue for you as well. I set Sam the task of tracking down the best free programs available today to enhance your productivity, gaming, and more. Meanwhile, Ian's been hard at work on his final piece looking at the past and all the innovations that came out of NASA's space flight programs. And I've got to grips building an upgrade machine, taking advantage of Intel's latest Core i5-11600K processor in the prestigious Lian Li PC-011-Dynamic chassis, buried in an older Z490 motherboard.

Of course, on top of that, we have a bevy of reviews, including a look at perhaps Intel's only strong outing this time around—the Core i5 I just mentioned—AMD's Radeon RX 6700 XT (another graphics card you can't buy), and more. We've also got a ton of tutorials and columns, plus a new batch of soul-destroying Blueprints for you to scratch your noggin over.

Finally, I just want to say I've finally made progress on cracking Future into action regarding subscription problems and to hopefully amp up the customer support you guys have been receiving. It looks as though we're going to be getting an online live chat system, which should help a lot, and they're also looking into getting a priority team set up specifically in the US. In the meantime, if you're still having trouble, please do contact me on the email address below.

As always, I hope you enjoy the latest issue of *Maximum PC*, stay safe out there! And until next time....

Zak is Maximum PC's *editor-in-chief and long-time staff member. He's been building PCs since he was 10, and is more than capable of butting heads with the biggest names in tech.*

↘ submit your questions to: editor@maximumpc.com

THE NEWS

Ryzen APUs Go Zen 3

AMD's chip machine continues to roll

IT'S USUALLY not long between new AMD chips, and this month the Ryzen 5000 series gets some new family members, sporting Zen 3 cores coupled to integrated graphics: Cezanne, replacing the previous Zen 2 Renoir chips. Slightly disappointingly, the graphics side of the equation remains the same, based on Vega. Hoping for an RDNA or even RDNA2 upgrade, as well as a die shrink and a new core architecture was asking a lot in one jump. The GPU speeds are actually slightly slower than the 4000-series APUs, although quite why isn't clear.

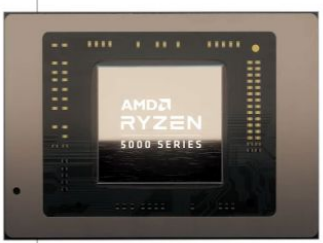
There are six new chips, split neatly into two groups, G and GE. The G chips have a TDP of 65W, sort of, using AMD's magical system for determining such things, which is divorced from actual power draw; it's more to do with what kind of cooling they'll need, and to match Intel figures, which are similarly dissociated from actual power consumption. The GE chips have a TDP of 35W. Of each type we have eight, six, and four-core versions, each with double that number of threads. All have PCIe 3.0. These are monolithic designs, unlike most of AMD's Ryzens built using chiplets.

The top chip is the Ryzen 7 5700G, which carries eight cores and eight Vega CUs, with a base clock of 3.8GHz, and a maximum boost of 4.6GHz. The price the GE chips pay for that lower power consumption is a lower base clock; the Ryzen 7 5700GE dips to 3.2GHz, with the same boost figure. AMD released the usual set of bar graphics, which show its new processors in a favorable light. It pitches the Ryzen 7 5700G against an Intel Core i7-10700, which it beats across the board on content creation and productivity by 30 percent or more. We'll have to wait for less partisan tests to believe this fully, though. The gaming performance gap looks even wider—if it's even close to true, these APUs should be speedy enough for some respectable mid-range gaming. AMD says the chips should be good for smooth 1080p action.

The new APUs are for original manufacturers only initially, so we've no consumer prices, but that's expected to change. AMD never officially sold its 4000-series Renoir APUs direct to the public, though a few did escape. These chips will be on sale to all and sundry later this year, which might bring some comfort if you're planning an AMD rig, but can't get the graphics card you want yet. One good new change is that AMD has sorted the strange practice of naming chips with integrated graphics differently, pitching them one generation higher than the vanilla versions, which is confusing to say the least. Now the 5000-series Ryzens are all Zen 3 and 7nm, we think, or will be soon anyway.

AMD hasn't shifted to Zen 3 on all the family yet, though. Threadripper is still to come. Rumor has it that it could well be coming this summer. However, it's not quite all rosy in the Zen 3 garden—a new vulnerability has been found and published by AMD. It exploits PSF, Predictive Store Forwarding, which is a type of speculative execution or branch prediction. It's generally accurate, and when it misses, the processor is supposed to flush the pipeline. The effect of a wrong PSF speculation is similar, says AMD, to a speculative store bypass, or Spectre. Code could implement security control of some kind, which can be bypassed when PSF misses, such as when a browser includes malicious code, causing misses, and we get data "leakage." PSF can be switched off, which AMD recommends if you're worried. The performance hit for this appears to be 1–2 percent. Don't panic, this isn't a Spectre-level problem, just a vague theoretical problem, but it is embarrassing.

Meanwhile, we have "leaked" slides showing an AMD road map, and a lot of rumors about AMD's next moves. The slides show the 6nm Zen 3+ Ryzen 6000 coming possibly as early as this year, code name Warhol. This gives a small IPC gain and other goodies. After this, we move to 5nm Zen 4 as early as next year. Speculation has this returning IPC gains of 25 percent or better. Intel's Alder Lake will have something to chew on. Yes, it's all whispers, but it isn't too far from the truth. AMD is still charging ahead as fast as ever. **–CL**



> "Welcome to Zen 3 with integrated graphics, claimed by AMD to be the fastest ever desktop APU. We shall see."

© AMD

ANTI-MINING MOVES

GEFORCE RTX 3060 MODIFIED TO DEFEAT CRYPTO

NVIDIA HAS PREVIOUSLY ATTEMPTED to stop cryptocurrency—specifically Etherium—miners using its GeForce RTX 3060 cards. It had limited success. The block was built into the card's driver, and was circumnavigated by the miners, who promptly devoured card supplies. Now Nvidia is making another attempt to stop the card's diversion from gaming. The GA106-300 GPU is being replaced by the GA106-302. It has a new PCI Device ID, so existing drivers won't work, and will include "other methods" to stop mining. Reportedly, when the card detects the command to perform the hash operation, it cuts the GPU speed in half. You won't know which version you have until you try using it. We want this on all graphics cards, covering all types of cryptocurrency, so the miners have to buy dedicated mining cards, and we can get back to building gaming rigs. **–CL**

NVIDIA'S ARM DEAL DIES

Politics interrupts business

NVIDIA wants to buy Arm, and was willing to pay $40 billion for the privilege. Arm is a British company that designs chips, and is good at it. Its designs are in most of the world's smartphones, as well as many supercomputers. It's also a leading AI company, and has design centers around the world, including the United States and China. It is one of the few top-tier chip businesses left in Europe. It's owned by SoftBank, a Japanese conglomerate holding company. So why can't a US company buy a Japanese-owned company? Politics. The UK government has issued an intervention notice, and the European Union has raised concerns. China isn't happy either; it worries about too much technical power in US hands. Reportedly, it's this Chinese opposition that is really stopping the deal. Currently, China can do business with Arm; if Nvidia were to own it, US trade restrictions come into play. In 2018, Chinese opposition killed Qualcomm's attempt to buy Dutch company NXP Semiconductors for the same reason. For now, the deal is dead. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

PC SALES BOOM
Year on year sales figures for the first quarter of the year show over a 55 percent rise in PC sales, with 84 million sold.

ALIENWARE GOES AMD
The company is to ship its first AMD-powered laptop since 2007, based around the Ryzen Mobile 5000-series.

INTEL TO MAKE CAR CHIPS
To ease shortages and use spare capacity, Intel is to start making chips for cars within nine months.

TRAGEDIES

APP STEALS BITCOIN
After using a five-star app from Apple's App Store to check his Bitcoin balance, one customer found it had stolen them.

PHONE ZOMBIE APP
Google's Wellbeing app now reminds you to look up when walking and using your phone.

UPDATE HITS GAMING
The latest Win 10 update has brought reports of trashed gaming frame rates. The only cure so far is to uninstall the update.

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RETURN OF THE TICK-TOCK

New chief sets out Intel's future

INTEL HAS A NEW CEO. Pat Gelsinger returned to Intel earlier this year; he previously spent 30 years there, and helped design the 80486 architecture (you may have to ask your dad about that one). He's made several announcements outlining Intel's plans. The company is to build two big new fabs in Arizona, due to start limited production in 2024. The process is unspecified, but 7nm seems to be a safe bet; the first 7nm chips, Meteor Lake, are due in 2023.

There will also be a return to the tick-tock model, where a new architecture is followed by a die shrink, then back to a new architecture. It's how Intel operated before Skylake, after which it was forced, for various reasons, to repeatedly tick. After that there was a three-stage process, architecture, optimization model, which has looked wobbly. Gelsinger promises to lead the company back to "unquestioned CPU leadership performance" by 2025. Will Intel need outside help? There are hints that it will, including references to "high performance compute products" being built for it (sounds like processors, right?). It would be a quite a jump, but there's no doubt it is a long way behind here—TSMC is testing 5nm now, and AMD's Zen 4 is expected to use it next year. Intel will also be building chips for others, hiring out spare fabrication capacity.

Gelsinger's outline is bold, but Intel has spent too much of the last couple of years chasing subsidiary markets while the one thing it should do well—making the best desktop chips it can—slipped away from it. The next two or three years will be the biggest overhaul the company has had in a long time: new fabs, new partnerships, and getting that jump to 7nm and beyond worked out. What is good for Intel will be good for us, too. The main reason AMD is so competitive now is that it had to fight Intel. **–CL**

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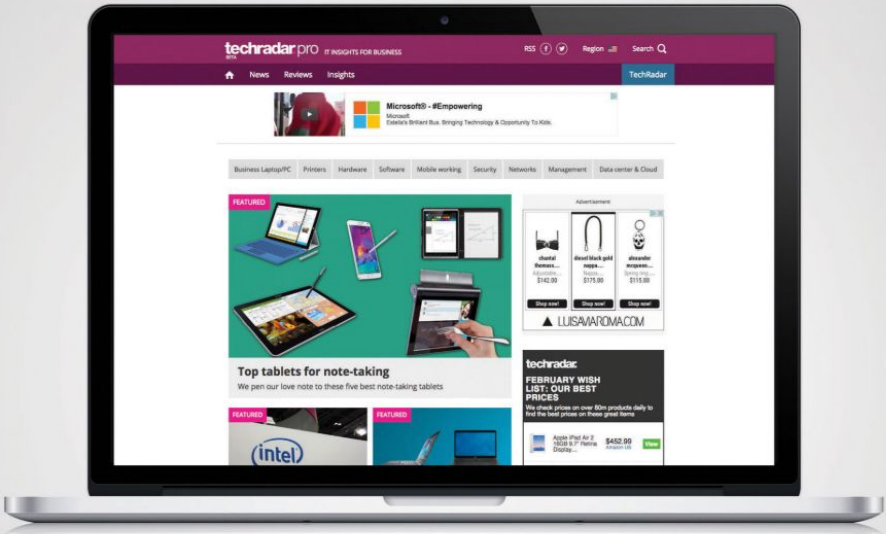
IT INSIGHTS FOR BUSINESS



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HoloLens Lands Plum Contract

MICROSOFT'S AUGMENTED HEADSET, the HoloLens, has found a large order at last. The US military has placed a contract worth $21.9 billion. The headsets will form part of an Integrated Visual Augmentation System (IVAS). An army announcement said that the IVAS offers "existing high-resolution night, thermal, and soldier-borne sensors integrated into a unified heads up display to provide improved situational awareness, target engagement, and informed decision-making." Microsoft was less aggressive and wordy, stating that the IVAS will "keep soldiers safer and make them more effective." It brings some significant abilities, including 80-degree night vision, instant sign translations, integrated navigation, and a link to your rifle's scope, so you can keep your head out of trouble as you fire around corners. The aim is to deliver 120,000 headsets over the next 10 years, at about $200,000 per soldier.

HoloLens has many interesting applications, but Microsoft has always been reluctant to talk about sales figures. It first surfaced in 2016, costing over $3,000. By the summer of 2018, it had sold roughly 50,000 sets. 2019 saw HoloLens 2, and Microsoft sold a mere "tens of thousands" in the first nine months. But playing the long game has paid off. For a start, it gets a huge cash injection for development. Previous attempts at heads-up displays haven't been popular with soldiers on the ground. It'll add weight and complexity to the already copious amount of gear, but the army clearly has faith in the system, and it can do some clever stuff. **–CL**

The HoloLens is to be part of a US military integrated augmented reality and communication system.

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Speedboats and Graphics Cards

Cryptocurrency miners are buying every good graphics card they can find, and where there's demand like this, you can expect the interest of the less respectable members of society. Police in Hong Kong noticed a fishing boat unloading cargo into a speedboat. The speedboat escaped after a high-speed chase; the fishing boat wasn't so lucky. The illicit cargo included the expected shark fins, plus a batch of 300 Nvidia CHP ^{0} cards. This is the entry-level version of Nvidia's new dedicated mining cards, retailing at over $700—if you can find them. You know you have a hot ticket item when it's being unloaded into a boat in the dead of night. **–CL**

The End for Old PlayStations?

Sony is to close the online store for the PlayStation 3. You'll still be able to play games you have, but that's it for new thrills. The PS3 and PS4 have CMOS batteries to keep the system clock ticking; if this dies, the box needs to connect to PlayStation Network to confirm the time. The machines also check on a game's legitimacy. The result is that when the CMOS battery fails, there'll be trouble. It's not complete death for the PS3, but without those servers, the PS4 is a brick. The PS3 and eventually the PS4 are living on borrowed time, but it's hoped that Sony will initiate a firmware update to keep these older consoles going, and please the trend for retro gaming. **–CL**

ONE BILLION ACCOUNTS STOLEN

Social media targeted

APRIL was not a good month for online security as two huge data breaches came to light. First was Facebook. An anonymous user on a hacking forum posted details from over 533 million Facebook accounts, including full names, birthdays, email addresses, phone numbers, and other goodies. Facebook said the data had been scraped employing a vulnerability that it had fixed in 2019, so at least the data wasn't current. But your name and birthday are unlikely to have changed since then. Two weeks later came news of a similar attack targeting LinkedIn. Its servers suffered a data scraping that harvested details from over 500 million accounts. Again, the details include account IDs, full names, personal email addresses, phone numbers, social media links, and more. Two million profiles have been released as proof of the attack on a hacker forum, the remaining accounts are up for sale. LinkedIn said it was "investigating this issue," and that the "dataset appears to include publicly viewable information." True, but unhelpful. These two breaches provide rich resources for "bad actor" attacks, targeted social-engineering, and worse. Tech companies often demand we submit personal information before we can access their services, but apparently even the biggest can't be trusted to keep it safe. There is concern over the uses of commercially constructed databases of personal information, and these two breaches highlight the ability to build similar databases outside the law. Perhaps the genie is out of the bottle; once we've scattered our details across the Internet, it becomes inevitable that these details become currency, for good, or ill, or yet more advertising. **–CL**

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Jarred Walton

TECH TALK

Nvidia's Grace CPU

WHEN NVIDIA ANNOUNCED it was buying ARM, the intent was clear: Nvidia wanted a way to compete in the CPU space. That's set to happen in 2023 with the arrival of the Grace CPUs. It's still a way off, but the specs already look impressive. The ARM acquisition paves the way for Nvidia to attempt to do in the CPU space what it's been doing with GPUs for over 20 years.

A decade ago, we first heard about Project Denver, a CPU architecture that would use binary translation to provide x86 compatibility. Intel blocked the x86 compatible aspect, but the chip did see the light of day in a few products, such as the Nexus 9 tablet. With the rise of ARM processors that power nearly all phones and tablets, plus some laptops and even servers, x86 compatibility is a must-have no more.

Grace focuses on Nvidia's strong points: AI and deep learning. The company claims it delivers 10 times more performance than the fastest servers, at least in AI and HPC workloads. That will almost certainly come via vector extensions that boost performance in matrix computations, but Grace will also boost higher bandwidth and efficiency, thanks to LPDDR5x, and promises some of the fastest interconnects between CPUs and GPUs via NVLink: over 900GB/s cache coherent CPU-to-GPU NVLink, and more than 600GB/s CPU-to-CPU.

Nvidia hasn't talked core counts or clock frequencies yet, and while the rendered image suggests it might have 96 CPU cores, it's likely just a placeholder. Prior to the Nvidia acquisition, ARM had already disclosed its future high-performance Zeus CPU cores, which likely play a role in Grace given the time frame, though Nvidia now calls these ARM Neoverse cores. The ARM V1 platform includes support for all the latest whiz-bang tech: PCIe Gen5, DDR5, HBM2e or HMB3, and a CCIX 1.1 interconnect. Swap out CCIX for NVLink and link the CPU up with an Ampere Next GPU, and you have a potent starting point for a supercomputer node that can scale up to thousands of nodes.

Nvidia will power the ALPS supercomputer with Grace CPUs and next-gen GPUs.

Nvidia says its Grace CPU has a projected 300+ score in SPECrate_2017_int_base, and with eight GPUs in a single node, it would scale linearly to 2,400. That's impressive, considering even dual 64-core EPYC servers can't break 1,000—but most of that performance appears to come from the GPUs, not the Grace CPU.

Incidentally, the CPU is named after Grace Hopper, one of the pioneers of computer programming. Current indications are that Nvidia's post-Ampere GPU architecture will be code-named Hopper, so it will combine CPUs and GPUs to give double honors. Nvidia also revealed a tentative road map with "Grace Next" CPUs coming in 2025, and while we're on the subject, "Ampere Next Next" should show up in 2024—two years after Hopper (aka "Ampere Next").

Perhaps more interesting is where else we might see the Grace Hopper combo show up. It's a safe bet that Nvidia's plans don't end with supercomputers. Look at the laptop world and Nvidia already discusses that as an almost entirely separate market from desktop gaming PCs. We've also seen a few laptops testing the Windows on ARM possibilities—and, of course, there's Apple's M1 that eschews Windows and x86 in favor of an all-Apple design.

Officially, there's no word of consumer variants of Grace or Hopper yet, but we know they're coming. Nvidia still has its roots in the gaming market, and building a better gaming laptop—one that can play games untethered for many hours—would be impressive. Getting game developers to jump ship from x86 to ARM would have been practically unthinkable five years back, but with Nvidia, Apple, and others involved, it becomes less a matter of "if" and more "when" we'll see high-end gaming laptops running all-Nvidia processors. If not Grace Hopper in 2023, certainly the Grace Next CPUs of 2025 will pair up nicely with whatever comes after Hopper.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

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DOCTOR

THIS MONTH THE DOCTOR TACKLES...

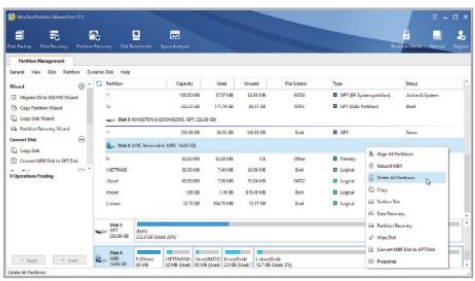
> Faulty Internet Gear
> SD Formatting Issue
> Streaming MP4s

Frame Stutter Problem

Doc, I'm experiencing an intermittent frame stutter issue in games as varied as *World of Warships* and *Ghost Recon Breakpoint*. It's not tied to graphics quality settings, as I've tried everything from maxed out to turning them down to mud, and still have the issue. I've tried killing all background apps/processes, I update regularly, whether BIOS, drivers, or firmware. I've tried stock voltages, PBO enabled, Ryzen Master OC, and so on but can't resolve it.

I built my PC in November 2019—key specs are Gigabyte Aorus Ultra X570 MB, AMD Ryzen 3800X CPU, 32GB (4x 8GB) DDR 3600 RAM with XMP enabled, plenty of cooling, 2TB Seagate Firecuda PCIe 4.0 OS drive, 1TB Samsung 970 Evo PCIe 3.0 auxiliary drive, 2x 3TB Seagate mechanical drives in RAID 1, Windows 10 Home, and I reused my GeForce GTX 1080 Ti from my old rig. My temps are all far below the max thresholds during gaming. I have tried disabling XMP and dropping the memory to 3,200MHz in the BIOS, but still no dice.

I'd love to upgrade to a Ryzen 5900X and an RTX 3080 to try to resolve this issue that way, but we all know the vaporware status of those. Any ideas of what is causing this? Am I running too much gear over the PCI interface and hitting bottlenecks, is the DDR4 3600 the issue, or something else entirely? **–BJ Koho**



MiniTool Partition Wizard can handle troublesome SD cards.

THE DOCTOR RESPONDS:

The Doc's first response was to ask about BJ's display setup, as the Internet was full of people exhibiting similar symptoms and finding common ground when looking into the connection to their monitors. BJ tried several of the solutions—he verified he was using the DisplayPort and bumped its response time to the maximum. He went into Device Manager, right-clicked "Communications Port," and choose "Properties → Port Settings," where he set "Flow control" to "Hardware," and disabled FIFO under "Advanced." He also uninstalled iCUE and disabled the 0 core in *Ghost Recon Breakpoint* in Task Manager

This helped a fair bit in *Ghost Recon Breakpoint*, although some frame stutter remained, but had no effect on *WoWS*. Undefeated, BJ kept plugging away and got back in touch two weeks later to share his final solution. While troubleshooting an issue with his Internet connection, BJ—with the aid of his ISP—traced a problem to his modem and router, both of which exhibited intermittent signal loss. He replaced these with a Netgear CM500 cable modem and Asus RT-AX82U router respectively, set up device priority for his PC and the requisite game profiles, and the problem vanished. BJ puts the problem down to the age of his old equipment, but wanted to share his fix in case it helped fellow readers.

SD Card Won't Format

Dear Doc, I have a question about my Dell XPS 13. It has a built-in microSD card reader but when I insert a card and try to format it, I get an error saying that the disk is in use, asking if I want to force-eject it. I've tried disabling background apps, looked into what's running with Process Explorer, and tried different tools to format the card, but no luck. One—GUI Format—throws up the same error, but with no option to force-eject. Another app, SmartDisk FAT32 Format Utility, won't recognize the card as an external drive unless it's plugged into an external reader/hub. Please help!

–Yosef Safdeye

THE DOCTOR RESPONDS:

Despite Yosef providing lots of information, we still needed

© MINITOOL PARTITION WIZARD

↘ submit your questions to: doctor@maximumpc.com

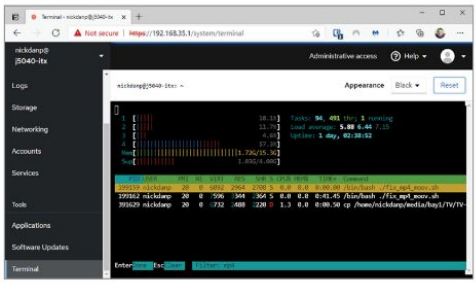
him to answer a few more questions, and Yosef was quick to reply. To summarize: The problem applied to all SD cards, as well as USB flash drives, and when using an external SD hub. The same error popped up when Yosef attempted to format the card in Windows, but clicking "Yes" led to the card being formatted successfully—however, Windows can't format 64GB-plus cards in FAT32 format, which is why he needs a third-party app. Finally, the same error popped up when attempting to eject the card—but this is common and trying again resulted in the "Safe to remove" message popping up.

One potential workaround arose from our conversations: If Yosef rebooted into Safe mode, he was able to format the card with no problems. Other suggested workarounds are to format the card in NTFS or exFAT first, before trying again with FAT32, or to use a different tool, such as MiniTool Partition Wizard (www.partitionwizard.com), which the Doc has used in the past to partition and format drives other tools wouldn't touch.

Yosef was worried the problem was linked to malware—it's not, but there's no harm in a quick security audit. Update and run a full scan with your existing tool—Yosef uses Microsoft Defender—then, if you want additional peace of mind, run scans with two further tools: Emsisoft Emergency Kit (www.emsisoft.com/en/home/emergencykit), which combines Emsisoft and Bitdefender virus scanners in a single tool, and Malwarebytes Anti-Malware (www.malwarebytes.com), which reverts to a free scan-and-remove tool after the 14-day trial. MBAM's reputation has taken a battering recently, but it does detect unwanted software other tools ignore, so is a good secondary tool.

Optimize MP4s

Hi Doc. I recently set up Plex on my Ubuntu server for all my ripped media only to discover loads of files kept buffering when I or friends accessed them remotely. I discovered something called the "moov atom" that needs to be placed at the start of my MP4 files (rather than the end) to facilitate streaming. I know now I need to check "Web Optimized" on the "Summary" tab in Handbrake to set this up for any future files I create, but what about the hundreds of files I've already got? **–Liam McShane**



Optimize MP4 files for streaming using MP4Box.

THE DOCTOR RESPONDS:

Luckily, there are tools that can move the required bits to the start of your file without having to reconvert it. This not only ensures the video and audio quality are unaffected, it's also a far quicker process. You can combine two free tools and a script to perform the task in the background from the command line. First, install the two tools: AtomicParsley for detecting files that need optimizing, plus MP4Box—part of GPAC —to perform the optimization, then download the script:

```
$ sudo apt update && sudo apt install atomicparsley gpac
$ wget http://muzso.hu/dfiles/public/fix_mp4_moov.sh
```

Open the script in nano ("nano fix_mp4_moov.sh"); the only part of this you need to modify is the "VIDEO_DIR=" variable, which you point to the directory containing media files—for example, VIDEO_DIR='/home/username/media/Movies/'. Save the file and exit. Now launch the script like so:

```
$ ./fix_mp4_moov.sh &
```

We've added the "&" operator to instruct the script to run in the background, so it doesn't tie up your terminal. The process can take hours, depending on how many files need optimizing, but you can monitor it using the "htop" tool. Once running (type "htop" and press Enter), press F4, and type "mp4" into the filter box. This enables you to monitor the running processes; you'll see AtomicParsley checking each file and then, when it finds one that needs optimizing, handing it over to MP4Box. Files are processed alphabetically, and are listed as they're being processed, providing a progress indicator. Press F10 to close htop and return to the command line at any time.

Alternate NAS Mobo

I read with interest in the February 2021 issue the letter regarding a NAS. I was wondering if the ASRock J4005B-ITX is a suitable substitute for the board mentioned (AS Rock's J5040-ITX)? The latter is out of stock at Newegg and way overpriced elsewhere.

–Anthrax.Ancient via Discord

THE DOCTOR RESPONDS:

The chip shortage means the J5040-ITX is now virtually impossible to get. It's a shame because it's the perfect board for a NAS. That said, you can do better than a J4005B-ITX—as others on the *Maximum PC* Discord server point out, it only offers two SATA ports, which limits you to two internal drives unless you use a plug-in SATA card, which won't perform as well as the native onboard SATA ports.

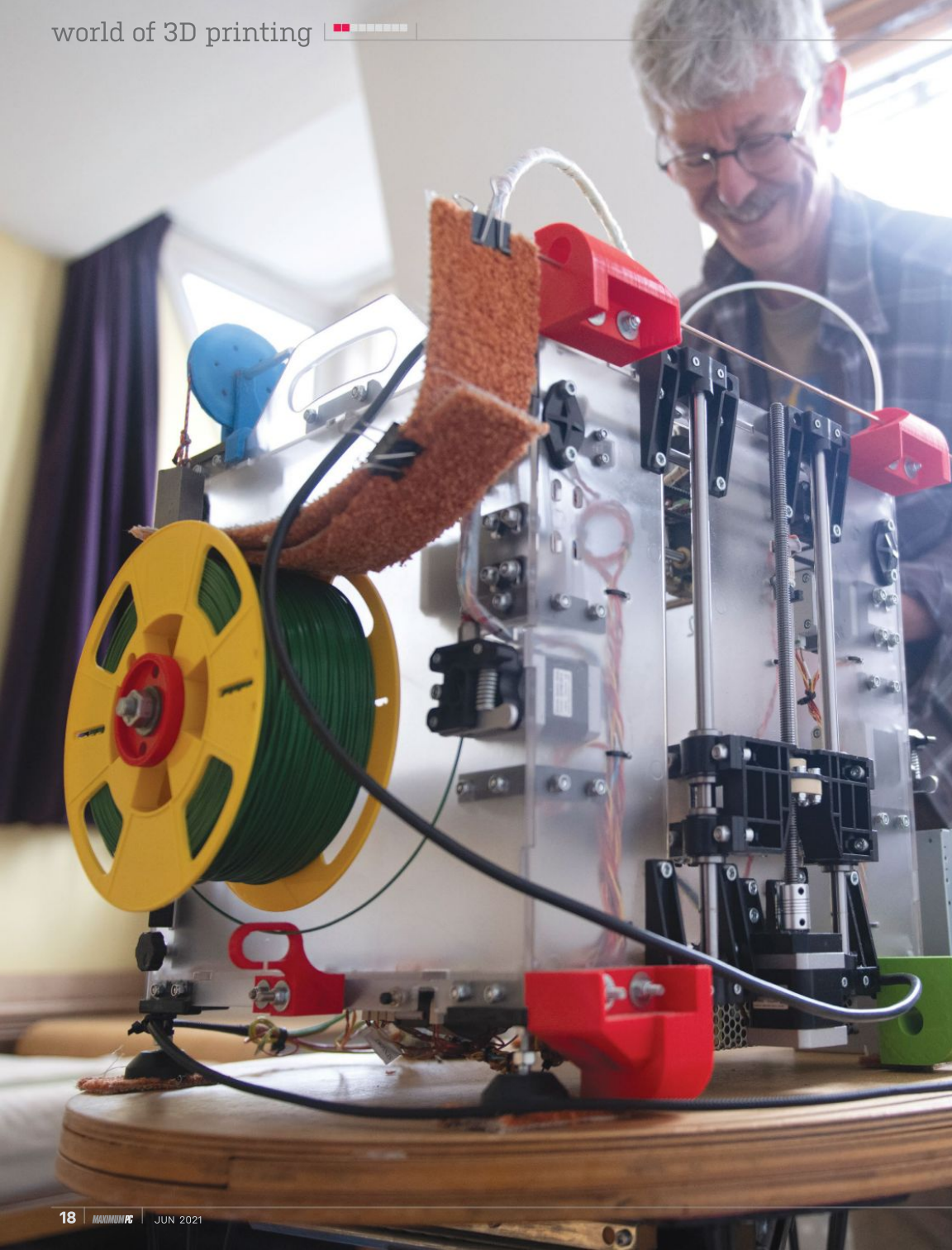
A better replacement is the ASRock J4125-ITX ($96.99, www.newegg.com), which—like the J5040-ITX—is a Gemini Lake Refresh board. It's a Celeron rather than a Pentium processor, but is quicker than the J4005, and comes within 10–20 percent of the J5040's performance. Crucially, the J4125 boasts the same Intel 600 graphics, so it's suitable for hardware transcoding media streams if you want to use the NAS as a low-powered media server.

There are two models. The regular J4125-ITX has four onboard SATA3 ports—two native ports, plus two ASMedia ASM1061 ports. The J4125B-ITX ($84.99, www.newegg.com) has only two native SATA ports. If you only need up to four drives, the J4125-ITX is clearly the better option, but what if you need more?

The J4125-ITX has a single PCIe 2.0 x1 expansion slot, and you can pick up two- and four-port SATA PCIe x1 cards cheaply on eBay. But with the bandwidth limited to around 500MB/s, and shared with the onboard ASM1061 ports, you won't get maximum performance from all your drives. The J4125B-ITX supports a PCIe 2.0 x16 slot, which maxes out at around 8GB/s, making it more suited for setups where five or more drives are needed; expect to pay north of $60 for an eight-port SATA PCIe x16 card.

Both—like the J5040-ITX—also sport an M.2 slot, but this doesn't support M.2 boot drives. M.2 is overkill for a server that's on 24/7 anyway; just plug an SSD drive into one of the native SATA ports, and install your OS on that. Choose an SSD designed for the unique demands of network servers; the Doc recommends the WD Red SSD 500GB ($75, www.newegg.com).

© MP4BOX



JUMPING INTO THE WORLD OF 3D PRINTING

New to 3D printing? Want to advance your skills? *Kris Butterill* shows you the ropes

MOST PEOPLE have at least heard of 3D printing by now. Not everyone, however, fully understands what it is, how it works, what can be created, its limitations, or even how 3D printing is driving technological advancement throughout the world and changing our everyday lives. 3D printing has exploded in popularity over recent years, and with the technology becoming more affordable, it's now more accessible than ever. 3D printing is an ever-growing platform for many hobbyists, enthusiasts, and professionals alike, and is a technology that offers a feature set like no other.

We are talking about a technology that is being used in a vast variety of fields, from product prototyping and construction to medicine, including customized prosthetics, orthotics, and more. It's a process that is truly changing people's lives for the better and, in most cases, is driving to reduce the by-products and waste created in manufacturing.

We want to guide you through the fundamentals of 3D printing, and how to get started, should you be in the market for a 3D printer. Maybe you just want to tinker, replace a broken part that can no longer be purchased off the shelf, prototype an idea, or simply play around and print cool things. No matter what your use case, delving into 3D printing can be a little daunting—trust us, we've been there. So, let's get started with the basics....

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Everything from prosthetic limbs to cartoon characters can be created with a 3D printer.

WHAT IS 3D PRINTING?

To start off, let's cover what 3D printing actually is. In simple terms, it's a process whereby a solid object is created by what's known as additive manufacturing, utilizing a digital file as a blueprint. A typical manufacturing process—milling, for example—is a subtractive manufacturing operation, where material is removed to create the desired object. This is a process that creates a lot of waste material; in some cases, it's possible to recycle or even sell these by-products of manufacturing.

3D printing is the exact opposite, where material is added to create an object. And here's the cool part: 3D printing can create more complex shapes, and in the process, reduce the amount of waste generated, because it only uses what it needs for the object itself and any support structure.

WHO IS 3D PRINTING FOR?

Everybody. As we said in the intro, the technology is becoming more and more accessible and affordable for mainstream users. This is not a technology reserved for mass-market product manufacture, specialist roles or applications, or even medical progression; it truly is something that anyone can use.

Throughout the Covid-19 pandemic, 3D printing has been a huge resource for the production of PPE—respirator valves, face shields, and mask extenders, in particular. There was a rallying cry throughout the 3D printing community to help provide items during the shortages of PPE, and there are people, just like you, printing supplies to help out all over the world. Linus Sebastian, Joel Telling, and many other popular YouTube stars have all been involved in one of the largest 3D printing challenges of our time to combat these shortages. Using their reach, the community has been pulling together to do their bit, and it makes you realize that 3D printing really has reached every corner of the globe.

TYPES OF 3D PRINTERS

Hopefully, with what you have read so far, you are still curious about 3D printing, and would like to get involved and have a go at printing your first model. So, it's now time to talk about the types of 3D printers available—there are other methods of 3D printing, but the ones we mention here are the most common. We have also included a few pros and cons for each, to give you a better understanding of what each type brings to the party.

•**FDM** An FDM printer, or fused deposition modeling printer, is most likely what you picture when thinking about 3D printing—they are hugely popular and, in the most part, known for their ease of use. An FDM printer works with a huge variety of plastics—or, as they are more commonly known, filaments—each with their own positive and negative characteristics. Filaments are typically available in 1.75mm diameter, and are presented like a reel of cable, feeding the loose end into the printer via a tube, to be heated and extruded. By extruding the plastic, each layer of a model is produced along an X, Y, and Z axis.

FDM printers are typically found in two variants: Cartesian and delta. The difference between the two is how the machine moves and separates the X, Y, and Z axis. For a Cartesian printer, each element, or axis, only moves in one direction, while a delta-style printer can freely and quickly move in any direction.

FDM printers are also quite safe, despite using heat to melt the filament; the only real concern is the release of VOCs (volatile organic compounds). Make sure that you are in a ventilated area, check the manufacturer's guidance, and you should be good to go. These printers are the most affordable, and some even use 3D printed parts themselves, so you can always print spares if components break.

Recycling FDM prints is a little more challenging, given the wide range of

An orthopaedic medical product designer uses CAD to develop equipment on a computer before the final device is created using 3D printing.

The Prusa Mk3 with multi-material upgrade, a typical Cartesian-style 3D printer.

Delta print heads can move in any direction quickly and easily.

© GETTY IMAGES, PRUSA/PRUSA MK3, MONOPRICE.COM/DELTA VARIANT PRINT HEAD

The coronavirus pandemic saw 3D printers come into their own as users around the world put them to use making PPE to combat the global shortage.

plastics that can be printed. They are also not the most accurate printers, but for everyday use and the average consumer, tolerances are not going to be massively important. Energy use can be fairly high, though, especially with long-duration prints; heating a printer to 200 C for more than a few hours does start to get that electric meter spinning.

•SLA/DLP PRINTERS Stereolithography (SLA) printers are wildly different from FDM printers. SLA was also the first commercially recognized 3D printer, and the method doesn't use plastic, but rather resin. These printers work by firing a laser into a vat of material, curing the resin in a very controlled and precise way for accurate model production.

The print bed is lowered into the resin and then, by using mirrors to direct a UV laser, the print is formed, layer by layer, hardening almost instantly. Once the print is complete, resin printers require each model to be rinsed off using a solvent to remove any uncured resin.

Resin types include standard, clear, castable, and tough, giving a variety of use cases. The high-quality prints give those looking for something more than an FDM printer can offer something else to consider. They provide strong, structured prints, fast print time, and any unused resin can be saved for the next print. The downside to SLA printers is that resins smell, there is always a high percentage chance that you will spill something, and PPE is needed when handling them. The print process is also more complex, requiring additional steps before the model is ready, and the printers are more costly in terms of purchase and running costs. The print bed size is also a consideration, again depending on the use case. To put this in perspective, the Prusa Mk3S FDM printer, for example, offers a print bed of 9.8 x 8.3 x 8.3 inches, while its resin counterpart, the SL1, has a print area of only 4.7 x 2.4 x 5.9 inches.

Digital light processing printers are very similar to SLA printers; a DLP printer again doesn't use filament to create a model, but uses resin. They are also built around a container that houses resin, but use a digital projector screen to "flash" the print image, instead of using a UV laser. Once again, it's a rather complex science, and print quality for most DLP 3D printers varies between around 35 and 100 microns. The resolution comparison between an SLA and DLP printer can be quite in-depth, because a UV laser uses a dot, whereas a DLP printer uses a pixel. In general, both offer excellent print quality and precision.

•SLS PRINTERS Selective laser sintering printers once again use a laser to produce a print. They are a popular choice in the commercial and manufacturing world. They work by dispersing a powder on the print bed. The printer heats this powder to slightly below its melting temperature, then the laser is fired to specific parts of the powder, heating it to its melting point, and fusing it. The unfused powder acts as a support material while the part

The Formlabs Form 3L stereolithography printer, looking suitably futuristic with its glowing innards.

The Prusa SL1 resin printer has a smaller bed than the company's FDM Mk3S model.

As the company name suggests, the Sinterit Lisa Pro is an SLS printer.

© BEN HASTY/MEDIANEWS GROUP/READING EAGLE VIA GETTY IMAGES. FORMLABS/FORM 3L. STEREOLITHOGRAPHY PRINTER. PRUSA/THE PRUSA SL1. SINTERIT/LISA PRO 3D PRINTER

FILAMENTS/MATERIALS

Now you're a little more informed about the types of printers available, what do you need to get them running? Well, your filament—or material—choices are certainly not in short supply, so let's take a closer look.

Filaments are essentially spools of plastic, like a cable reel. They are typically sold in 750g and 1kg spools, and are available in a variety of different types of plastic and colors. Specifically for use on an FDM printer, each type of plastic has its own unique qualities. There are now even wood-based, flexible, and carbon filaments available, so there will certainly be something to cover your use case. Below are what we consider to be the three most common types of FDM filaments, plus a little look at resin.

Brighten up your prints with a wide range of filament colors.

PLA

Polylactic acid is one of the most common filaments available. It's also a plant-derived plastic, which makes it a great renewable source of filament. However, given its natural characteristics, PLA does degrade over time in sunlight and with exposure to moisture, but for indoor use, or for projects that require little to no structural strength, PLA is the perfect material. PLA also requires a lower print temperature than other filaments—around 200 C—which can save on energy costs.

PETG

Polyethylene terephthalate glycol is another popular filament choice for hobbyists, but it does require higher temperatures than PLA—closer to 250 C. It has the advantage of a higher physical strength than PLA, and it can be used outdoors. PETG does not print as cleanly as PLA, though—it has a tendency to "string," dragging cobweb-like strands of filament as it prints, which require cleaning up after printing.

ABS

Acrylonitrile butadiene styrene is another low-cost filament that you can use on your FDM printer. It does have some drawbacks, as it tends to warp and shrink a little, and doesn't smell too good. ABS is already used in many industries, because it has great wear resistance. It does, however, need high temperatures and a heated bed to print.

Resin

Resin printers use, well, resin, rather than plastic, to form prints. The options are essentially split into three categories: standard, toughened, and medical grade. Standard resins are good for prototypes and small items, and come in a number of colors, but are generally not suitable for use on product runs. Toughened resins are more resilient, enabling them to be used in a much wider range of applications and where they are subjected to loads. Medical grade resins are used where clinical levels of quality are required, and can be used to print a whole range of items.

is being produced, and is then recycled in post-processing, when the model is removed from the print bed.

Nylon is a popular choice of material for an SLS printer, enabling strong parts to be produced. These parts, however, do have a rough surface finish that can be tumbled or blasted to smooth them off. Possibly the biggest advantage of SLS printers is the recycling of material that is used for supports; with other types of printers, this material is usually wasted.

SLS printers are typically expensive to purchase, however, making them prohibitive for most people. The models produced also have a cool-down time, so that for fast prototyping, they may not be the right choice. The most significant stumbling block, though, is simply that they require high-end technology and use a lot of energy, putting them out of reach for most people.

A CLOSER INSPECTION

We've briefly looked at several of the different types of 3D printers available, but let's take a closer look at one kind in particular to familiarize you with some of the most common parts. Given that FDM printers are the most widely used, and the most popular among hobbyists, we'll explore how they work in a little more depth. An FDM printer works by depositing layer upon layer of material, until the object is completed—like a stack of paper, where each sheet of paper is a cross section of the object. Alternately, imagine frosting a cake, squeezing out the cream in circles on top of the cake, and then going around again to make it taller. Some people compare it to a glue gun, squeezing out the molten glue, and as it cools, it dries as a solid in place.

There are a few terms and component names that you will read or hear about a lot in the world of 3D printers, so let's take a little time to clarify these now to avoid any confusion.

•**PRINT BED** The print bed is the area on which the model is built, created from the ground up, adding more filament on each pass. The print bed itself can be heated or non-heated, depending on the manufacturer. A heated bed keeps a constant temperature throughout the printing process, which helps prevent warping of the model as it cools. Some printers even offer a removable plate, to make detaching models easier, or have smooth and textured sheets, allowing the face of some models to have a slight pattern to them. The size of the print bed dictates how big an item you can print—in some cases, larger models are split down

© PRUSA3D

into multiple parts, so they can be glued together later on.

•HOT END A term for a group of components, hot ends incorporate the heater, temperature sensor, and nozzle. The filament comes in via the extruder, heats up to a molten state, and is then printed through the nozzle. Hot ends, as their name implies, get very hot—around 250 C—so they are insulated to protect us and the rest of the 3D printer. It's worth noting that different materials print best at different temperatures, and this is controlled through a piece of software called a slicer—more on that later.

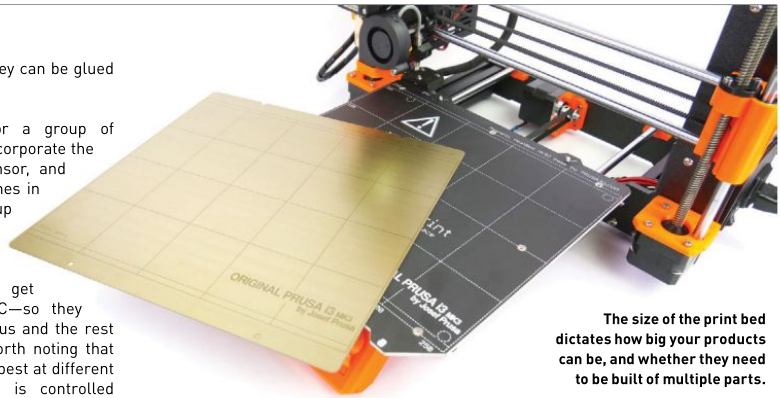
•EXTRUDER The job of the extruder is to pull the filament through from the spool, and push it into the hot end of the printer, so it can be heated. The force behind this process then allows the molten plastic to flow out of the nozzle. This is typically done using a pair of gears and a motor, dictating the speed of the print. They are usually found at the print head assembly. Some printers also come with dual extruders, for printing in two different colors. Another type of extruder uses what is called a Bowden tube, where the extruder is not directly linked to the print head; the tube directs the filament from the extruder to the hot end.

•NOZZLE Most printers use a standard 0.4mm nozzle, but there are many sizes available. These have a direct impact on the finished quality of your print—the smaller the nozzle diameter, the higher resolution the print. Nozzles are usually constructed of brass, but there are specialist nozzles available for coarse filaments that are hardened and made of stainless steel. Coarse filaments cause wear to nozzles, and affect the final print quality as they grind away the opening.

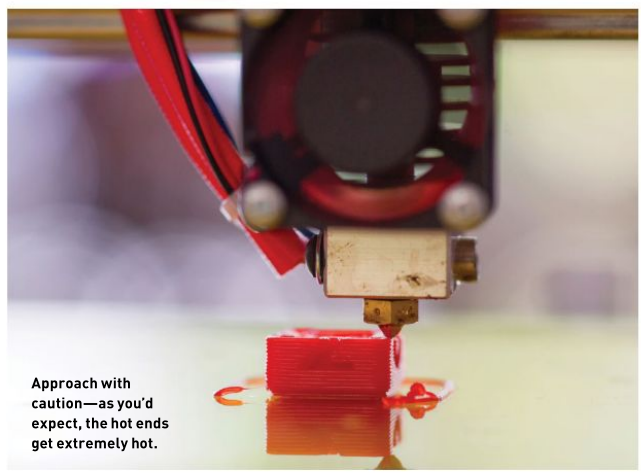
INSIDE INFORMATION

While it's not imperative that you know everything about how a 3D printer works or how it's assembled, it can be beneficial Learning the basics about how your printer is constructed will help in the future if you run into issues or a part fails. It doesn't matter what printer you have, at some point something will go wrong—a print may fail midway through, or a belt may snap. You'll also have to do some maintenance, so it's good to know your way around your machine.

Some manufacturers even give you the choice to purchase their machines as a



The size of the print bed dictates how big your products can be, and whether they need to be built of multiple parts.



Approach with caution—as you'd expect, the hot ends get extremely hot.

The smaller the nozzle, the better the end result.

A Bowden tube works differently from a standard extruder, directing filament to the hot end.

© PRUSA3D/PRINT BED WITH REMOVABLE PLATE, GETTY IMAGES; CREALITY/CR10 BOWDEN TUBE STYLE 3D PRINTER, OLSSON/OOZNEST

kit, as Prusa does with its MK3S and Mini. This may seem like a daunting task at first, but it's really worth considering—it's not only likely to be easier than you expect, but it can teach you so much about how the printer actually works, too. Prusa is renowned for its excellent assembly guide and forums. Its assembly instructions are also available via the company's website, with the facility to ask questions under each specific page. By doing this, Prusa can review the questions and then revise its assembly guide to be even clearer. It also allows other users to contribute their own experiences to help out.

THE PROCESS OF 3D PRINTING

Once you're ready to start printing, how do you turn your idea into reality? The process involves a few steps, so let's break it down.

•3D MODELS The whole procedure starts with an idea that can be transformed into a 3D model, created entirely by you, or sourced from one of the many design websites available. There are some great resources out there should you simply want to play around and print some cool models—these can vary from simplistic day-to-day items to help around the home, to more complex items, including those that require multiple 3D printed parts to complete them.

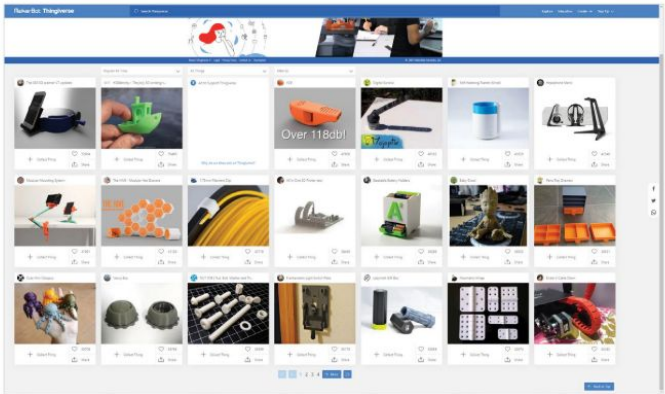
Thingiverse (www.thingiverse.com) is one of the most popular websites for downloading 3D models. People can also remix these models and re-upload them, refining the original or adding their own twist. If you're looking for models to print and sell, however, Thingiverse may not be for you, as most models fall under a type of licensing. For selling prints, you are best off creating your own models.

•CAD Every single model is designed in CAD (computer aided design) software, then exported in a special file format, typically OBJ or STL. If you want to get into the design side, rather than downloading models, there's a lot of options. From basic, beginner-level software, such as TinkerCAD, through to the highly complex Fusion 360, there is something to suit every experience level. There are also offerings from SketchUp, Blender, FreeCAD, and many more.

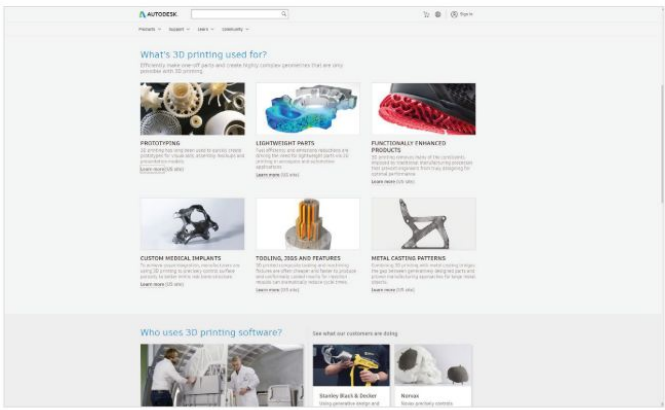
Your choice will depend on your level of experience; for newcomers, we recommend using a basic tool to get the hang of things, then moving up to something more in-depth. Some software packages are freeware, others come with a trial, while some require a license to use. It's also worth noting that if you wish to replicate real-world items, there are 3D scanners available. While this won't be suitable for everyone, it is an option for specific applications.

•SLICER Now the magic can begin. After you've designed your model and exported the file, you import the special file type to another piece of software, called a slicer. The slicer is probably the most important part of the process. It essentially controls exactly how the 3D model that you imported is produced on your printer. You have many options available here in terms of not only what slicer is used—most are free—but also with regard to controlling the final output that will be brought to life on the printer itself.

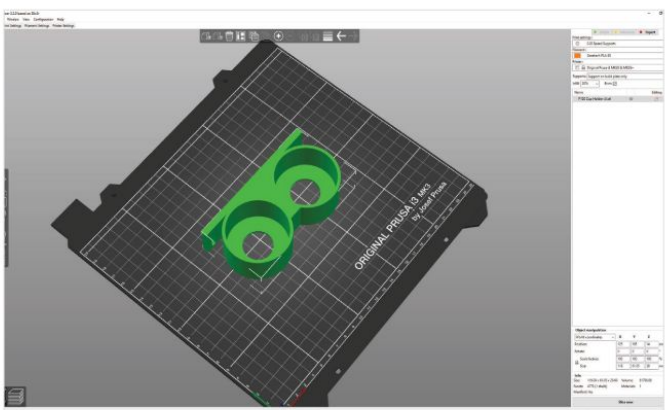
Think of it like the graphics options menu in a game. The resolution, in 3D printing terms, is how thin or thick each layer is. If you want more detail, you need higher resolution, meaning more layers to your print. This is just like having a 4K monitor but outputting at 1080p—the physical size is the same, but the detail is lower. Whack that resolution up to 4K—or, in printing talk, reduce the layer height—



Sometimes, the hardest part of 3D printing is choosing what to print.



Using Fusion 360 for designing models is challenging, but can be very, very rewarding.



PrusaSlicer is one of the best free slicers available.

© THINGIVERSE, AUTODESK, PRUSA3D

and the better the resolution, or detail, the print will be.

There are many options in a slicer—more than we have room for here—but once you've decided on the settings you want to print at, you export the final code that can be read by your 3D printer.

CHOOSING THE RIGHT PRINTER

Still with us? Good. So, you like the idea of rushing out to buy a shiny new 3D printer, but which one? The biggest? The most expensive? The most "liked" on social media? The one your buddy at work got for his birthday?

The answer is probably going to be none of the above, so let's discuss why.

It's now grown-up time, when you sit up, be honest, and think about your needs in terms of 3D printing. Just because a certain printer is the most expensive and has all the features, that doesn't make it right for you. You may not need all those features for the type of things you want to print, or the printer might be so big you have nowhere to put it. We need to take a step back and narrow things down a little.

Before we go any further, it's time to check a few details. Given that you're reading a PC magazine, we assume you have a fairly modern PC. This is obviously one of the first things you need—if you can't create or download a 3D object, you sure as hell aren't going to be able to print one. If your PC is a little dated, it may be worth looking into an upgrade, should you wish to create and edit your own models. If you are simply looking to download models and print them, the situation isn't so bad. You see, upgrades cost money, and if you need to upgrade your PC, the money will probably come out of your printer budget. Now, what suits one person may not suit another, but thinking about the points below will go a long way toward making sure that you don't blow a load of hard-earned cash on a printer that's not right for you. These points aren't in any particular order—you might think features are more important than budget, for instance—so you need to consider your own priorities.

•DO YOU NEED ONE? Before you decide on what printer to buy, you need to think about what you are going to use it for. If it's simply for a few quick projects and then it's going to be packed away, never to see the light of day again, it may be more worthwhile looking for a local maker space or online printing store to take care of the work for you. If this is going to be a realistic investment—for creating products or prototypes, say—it still might be worth ordering your first design from an online store. It's an economical way of

Join the conversation!

Discuss all things PC gaming with fellow readers at our official forums

forums.pcgamer.com

PC GAMER

finding out whether your idea or product is worth investing in.

•BUDGET 3D printers can vary in cost massively, but setting a realistic budget may help narrow down what choices you are limited to. A lot depends on the type of printer you are looking for, and what you wish to produce. The type of printer you need in order to produce the type of prints you want could be out of your budget, but you can look at alternatives.

•USE CASE What is it you want to do with your printer? Mass production, specific models, fast prototyping, miniatures with high details? The use case is possibly the most important aspect, as it dictates the type of printer and materials that can be used. If you need a flexible print, this narrows down the choice; highly detailed items may push you toward a different type of printer.

•PRINTER TYPE We've already covered the most common types of 3D printers available, so that should give you a heads-up as to what to look for. This links into the use case; deciding on the type of printer first, over the use case, limits your options further down the line.

•FEATURES Features vary wildly between printers, but the print resolution is a good starting point, and your choice may be influenced by this and how good you want your models to look. The print bed size dramatically affects what can be printed, or in how many parts. Time is money, so having to print multiple parts on a smaller bed might not be as cost-effective as the initial outlay for a bigger one. A safety feature such as auto cool-down when the printer has finished is a good one to look out for, as it helps to protect the printer, while reducing energy use. Multi-filament support, wireless printing, touchscreen interfaces, and camera support are also good features to consider.

•SIZE REQUIREMENT In terms of print area, that's covered above, but there's no point buying a massive 3D printer if you have nowhere to put it. Real estate is expensive; your printer's footprint can be the difference between having one larger or three smaller printers, say. Consider the trade-off—it may be more sensible to purchase more small printers if you are looking at batch production, where downtime if one fails won't have such a large impact over having one large printer.

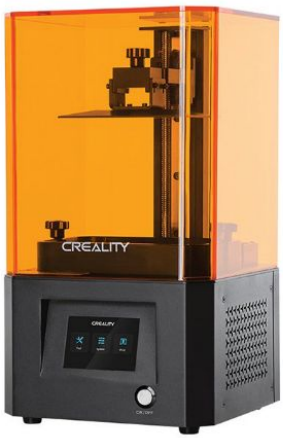
•SUPPORT It's worthwhile scouring user reviews, feedback, and the brand's customer support. Is there a dedicated user forum on the manufacturer's website, or a Facebook user support group? Remember that if something does go wrong, it's great to have that support ready and waiting in the background. If you pick a good manufacturer, with solid support, chances are your question has been asked before.

PRINT OUT

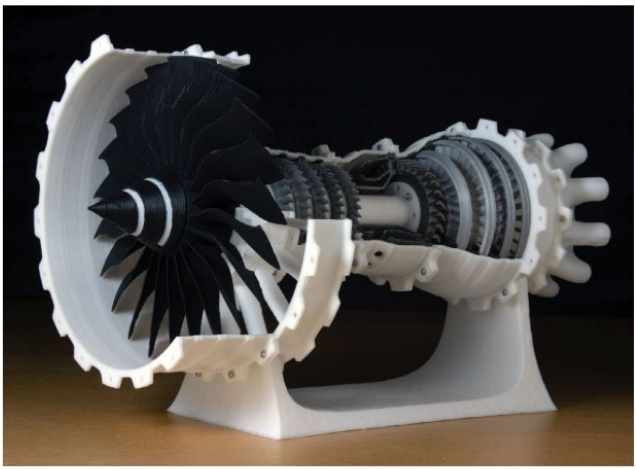
There you have it—an all-around look at getting started with 3D printing. If you were pretty clueless about the subject until now, hopefully this feature has answered a lot of the questions you had, and will potentially save you money and prevent you from making a mistake by buying a printer that's not right for you. One of the biggest conundrums you can face is deciding whether to spend extra money on a prebuilt printer rather than a kit. The price difference can be a few hundred dollars, but even if finances aren't an issue, buying a kit can teach you so much and be really enjoyable. It can really start your 3D printing journey on the right foot. Of course, buying a prebuilt printer isn't a bad thing by any means—we'd soon all be complaining if everything in life came as a kit.

Just make sure you pick what's right for you in terms of use case, budget, experience, and so on. If you take even a little of what we've talked about into consideration, you won't go far wrong, and if things do go awry, there should at least be a support group to help out. Watching that first print come to life is amazing. Sure, there's some fine-tuning to do, regardless of which printer you buy, but in the end, it's worth it, and you can create some truly fantastic models.

If you're into PC modding, a 3D printer offers endless possibilities. And what child of the eighties could resist building their very own proton pack from *Ghostbusters?* Yes, it's available on Thingiverse. Fancy an Iron Man helmet for comic cons, a self-watering plant pot as a gift, or even a model jet engine for the kids' homework? There's something for everyone, and involving the whole family not only educates, but makes 3D printing that little more special.



The Creality LD-002R 3D printer eschews filament in favor of resin.



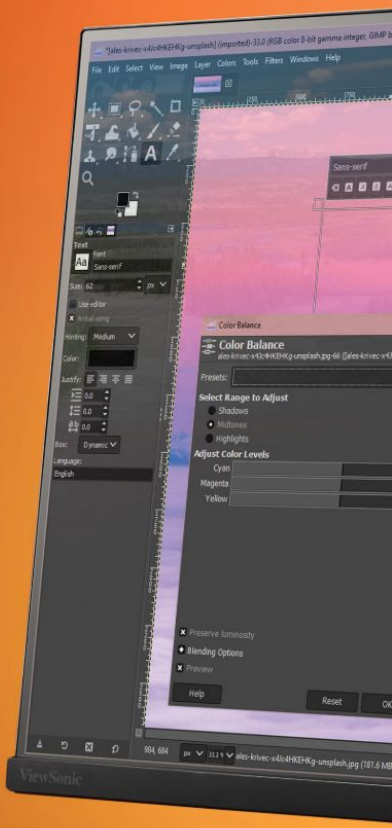
Science fair looming? Why not give the kids a hand with a 3D-printed jet engine scale model?

© GETTY IMAGES/ JOEL PAPALIN/EYEEM; CREALITY/THE CREALITY LD-002R RESIN 3D PRINTER

THE BEST OF THE FREEBIES

50 completely free programs you should install on your PC

SAM LEWIS



WE'RE NOT SAYING you should install all 50 of these programs at once, but these are our recommendations for software that we feel will hopefully benefit you in some way, give you a kick-ass experience, or simply add a little entertainment to your day. And who doesn't like a freebie?

Paying for things can get tiresome, not to mention expensive, but thankfully there are plenty of free alternatives or routes to take instead of delving deep into your pockets to buy an application. We've rounded up a wide range of programs here that enable you to improve your PC's efficiency, customize your rig, get creative, or just have some fun.

The free market has rapidly changed over the last decade. Cell phones have played a huge role in this transformation, because we've grown to expect more and more from free services. The quality of free applications available now compared to even a just few years ago has shifted massively. For instance, triple-A title *Call of Duty* is now offering a fully immersive and epic gaming experience with its battle royale game mode, "Warzone," taken from *Modern Warfare*—all for free. Of course, it's a clever way to entice you into the franchise, but the free gaming market has exploded because of titles like this. It sets a bar, with high expectations for the quality of free applications and games to continue upward. The free market is an exciting area to keep your eye on, so here's 50 of the best programs that won't cost you a dime.

Scale Image
Scale Image
Image Size
Width:
6269
Height:
3055
px
6269 × 3055 pixels
X resolution:
72.000
Y resolution:
72.000
pixels/in
Quality
Interpolation:
Cubic
Help
Reset
Scale
Cancel
Grunge 01 (256 × 256)
Splatters,
Spacing
20.0
Layers
Channels
Paths
Mode
Normal
Opacity
100.0
Lock:
ales-krivec-x4
Red
Green
Blue
Reset Range
Split view
Cancel

MAINTENANCE & REPAIR

01 TechPowerUp GPU-Z

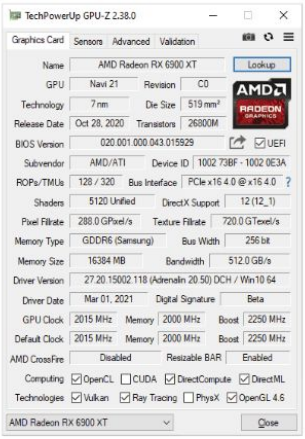
GPU-Z is a lightweight program that tells you everything you need to know about your graphics card. It's a quick, effortless solution to keeping tabs on lots of data in one place. You can check the GPU's BIOS version, when the card was released, the GPU clocks, and so on. Other metrics revealed by the software include temperature, core frequency, memory frequency, GPU load, and fan speed tracking. Who wouldn't want this data for free, and always just a few clicks away? ***www.techpowerup.com***

02 CPUID HWMonitor

As the name suggests, HWMonitor is a hardware monitor, and focuses on the health of your PC. The application enables you to take a look at the main health sensors, such as voltage, temperature, fan speed, and so on. It's a great place to check whether anything is a particular bottleneck if you're experiencing performance problems. It can help you identify why these issues are occurring, and confirm whether they're hardware-related. It's a free, easy-to-use PC doctor, and a big part of our testing suite here at the magazine, too. ***www.cpuid.com***

03 CCleaner

The more you use your PC, the more it becomes cluttered with unused files, settings, and junk, which all combine to slow down your once beautifully fluid machine. Obviously, this is far from ideal, but CCleaner is specifically designed to fight against the problem. It features a file cleaner to eliminate all the pesky excess for increased speed, a privacy protection tool to remove tracking and browsing data, and a health check to automatically analyze, fix, and tune your PC's performance. ***www.ccleaner.com***



Get the complete skinny on your graphics card with GPU-Z.

04 CPU-Z

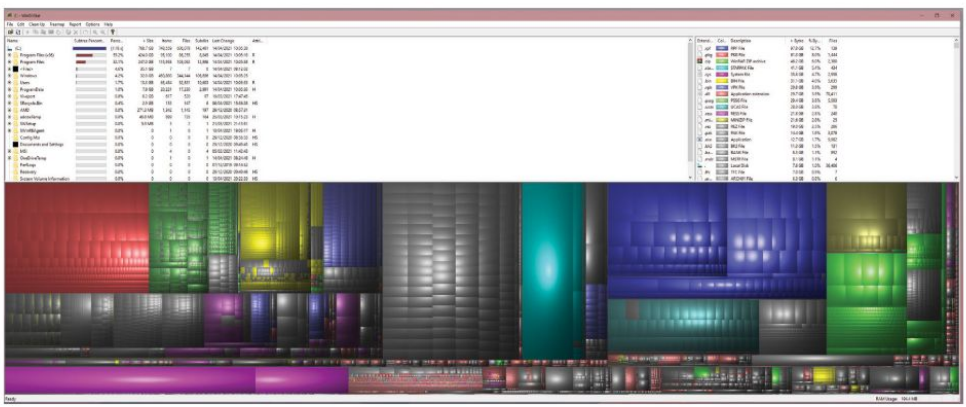
Here's a handy tool to reveal extra information about your CPU that Windows usually likes to keep hidden away. CPU-Z can tell you which processor you have, what chipset it uses, which motherboard is installed, and information about your memory, all in an easy-to-use lightweight application. It can be particularly useful for overclockers—even though it isn't specifically filled with overclocking features, it can help you create a report about your system's hardware specifications, which you can then use alongside HWMonitor. ***www.cpuid.com***

05 WinDirStat

If your PC is ever tight for space, WinDirStat can give you a helping hand with the matter. It's always a pain in the backside to figure out what's clogging up your PC's storage, but with this application, you get a visual report so you can literally see what's taking up all the room. Simply put, it is a disk usage statistics viewer and cleanup tool, which displays your storage as colorful visual tiles, so you can see where all your space has gone. ***https://windirstat.net***

06 Cinebench

Benchmarking is a great way to compare your rig against another PC's performance. The results can determine what you are able to get out of your PC and which elements are having the most impact on a game's frame rates, for instance. Cinebench is a visual benchmarking tool and the built-in leaderboards make it really easy to compare your results. It will give you an idea of whether your CPU is performing adequately compared to similar CPUs, and can give you an indication of how much of an improvement to performance a newer processor could add to your system. ***www.microsoft.com***



Visualizing storage with WinDirStat makes storage management a walk in the park.

©TECHPOWERUP.COM, WINDIRSTAT.NET

07 CrystalDiskMark

An open-source hard drive benchmarking tool, CrystalDiskMark is used to determine the read and write speeds of your SSD. It measures these speeds in sequential and random positions, with varying numbers of queues and threads. Like all benchmarks, you can use the data generated to compare your machine against other PCs to ensure yours is running up to speed, and that all your drives are operating correctly. ***https://crystalmark.info***

08 Recuva

Deleting the wrong file can give anybody a fright, but what if you do that and then proceed to delete it from the recycling bin, too? First of all: unlucky. Secondly, don't fret, because Recuva can help recover deleted files for you. When you delete a file on your thumb drive, hard drive, or SSD, the file isn't necessarily gone instantly. The block of space that the files were taking up has merely been relabeled as "free space" so it can eventually be used to store something else. Recuva can look to see if it's there, but the longer you leave it, the more likely it is that the file will have gone, so as soon as you accidentally delete something, find it on Recuva ASAP! ***www.ccleaner.com***

09 MediaInfo

Like a lot of these programs, the name kind of gives it away. If you need to find out information about a media file, MediaInfo will do just that. Right-click a video, for instance, and then click MediaInfo, and you can find its technical details all in one place. You can learn about the codec, video bitrate, audio stream, resolution, and FPS, for example. It's a good method of checking whether a video you've rendered has been saved to the correct format. ***https://mediaarea.net/en/MediaInfo***

10 FurMark

With its OpenGL routine, FurMark will put your GPU through its paces. The aim is to see how your GPU withstands its strenuous benchmarking test, to compare it against others. FurMark is no laughing matter, though, as it's been known to damage PCs, so take it steady, and make sure your cooling is up to scratch. The website gallery even shows hardware that has been defeated by this app, so make sure you know what you are doing. On the plus side, at least you don't have to pay for it. ***http://geeks3d.com/furmark***

f.lux: Reduce eyestrain, day and night
The sun is up. Light is making your body earlier.
Reduce Eyestrain
5900K
Solar time: 10:55, Sunrise: 6 hours ago, Wake: 4 hours ago
Circadian response: 62% (Ready to Work)
08:00
is my earliest wake time
Location: 51.5°N, 0.1°W
With its intuitive design, f.lux makes it easy to protect your eyes.

CUSTOMIZATION & EFFICIENCY

11 QTTabBar

A feature that should already be integrated into Windows Explorer is the use of tabs. Every time you open Windows Explorer, another window opens, and before you know it, your PC is flooded with pesky pop-ups. QTTabBar adds tabs to Windows Explorer, just like you see in a web browser, making file searching and transferring a much more fluid experience. Head to the "View" button in the taskbar, then to the "Options" drop-down, and click "QTTabBar" to enable it. Now just right-click a folder to open it in a new tab. It still looks and feels the same, but with the added benefit of tabs. ***http://qttabbar.wikidot.com***

12 f.lux

Blue light isn't great for your eyes, and using any sort of screen later on in the day or through the night can cause eye strain, which can massively impact your productivity, procrastination, gaming, or whatever else you are getting up to. What f.lux does is change the color temperature of your screen to match the time of day. This, in theory, should cause less eye strain, resulting in fewer headaches and a better night's sleep. And, of course, it's free, so it gets two thumbs up from us! ***https://justgetflux.com***

13 Rainmeter

An all-arounder for great visual PC customization. You can add skins to your desktop to make your computer your own and personalize it to your heart's content. Rainmeter is full of widgets to add to the desktop that give you advantages over the standard theme. You can add hardware-monitoring widgets to always keep an eye on your PC's performance, or add clocks, calendars, audio visualizers, and more. If you like making things your own and want to experiment with desktop customization, Rainmeter is a great shout. ***www.rainmeter.net***

14 Fences

This one certainly sits on the fence between customization and efficiency.... Ouch, that was painful—sorry! Anyway, Fences is a neat little piece of software that organizes your desktop icons and shortcuts into folders, much like those on your phone's home screen. Unfortunately, the latest version requires a few bucks, but you can go ahead and download an older version of the software for free or try the 30-day free trial option. ***www.oldversion.com/windows/fences-1-0-1***

15 Folder Marker

If you struggle with organizing your folders, this is another tool that can help you with getting everything sorted. It enables you to change icons and add color to your Windows folders. When working on large projects that use a load of different folders, it can be a pain navigating your way through the mess. Now you can right-click a folder, click "Folder Marker," then change the priority status or work type of the folder to make everything clear and tidy. It's a small program but it can really help with work efficiency. ***https://foldermarker.com/en/folder-marker-free/***

16 EarTrumpet

With a funky name like that, it's a shame the app isn't quite as exciting as its moniker implies, but it's a nifty and clever addition to your setup nonetheless. EarTrumpet is a sound icon that sits in the taskbar, but as it looks similar to the existing one, it's best to remove that

© JUSTGETFLUX.COM

first. What this app does over the standard sound control is change the volume of different sound sources. You can already do this if you're prepared to route around in the settings, but it's so much easier with EarTrumpet. ***www.microsoft.com***

17 ShareX

There are plenty of screen-capturing programs available, but ShareX is a particularly feature-packed example. It can capture screenshots and record with several options for how you want to capture, including full-screen, active window, active monitor, window menu, monitor menu, screen recording (GIF), scrolling capture, and webpage capture. This app makes it super easy to capture what you need, especially when paired with the provided shortcuts that you can find in the hotkey settings. ***www.microsoft.com***

18 Everything

Windows search is definitely an essential part of the operating system, but sometimes it can be painfully slow, and isn't always the easiest solution for finding exactly what you need on your PC. With Everything, it is very easy to find what you are looking for, making the whole process so much quicker. Another simple yet effective alternative to improve your overall PC experience. ***www.voidtools.com***

19 MyFolders

This effective tool adds a context menu that enables you to access your favorite folders from any right-click. Using MyFolders' interface, you can add your folders while organizing their location. Once activated, and with your selected folders added, you can now right-click anywhere, click "MyFolders," then "Go to," and you will find your selected folders available from the menu. A quick and easy to find what you need. ***www.coretechnologies.com/products/MyFolders/***

20 7 + Taskbar Tweaker

This taskbar customization tool falls right in the line of sight of people who like to have tight control over how their PC's interface looks and behaves. It makes your taskbar more interactive, giving you options to change the function of current buttons, alter how mouse buttons interact with the taskbar, change thumbnail previews, add functions to empty space, and much more. Add this free piece of software to interact with your PC exactly how you want. ***https://rammichael.com/7-taskbar-tweaker***

GAMER'S TOOLBOX

21 Razer Cortex

If you want an extra boost that focuses your PC's power on the things that really matter, look no further. Use Razer's suite of gaming optimization tools to achieve higher frame rates and loading times. It also features a system booster that automatically detects and deletes junk files to free up space, similar to CCleaner. A great addition to help your gaming experience. ***www.razer.com/cortex***

22 LaunchBox

If you enjoy dabbling with emulators, LaunchBox is an excellent launcher to store and display your retro collection all in one place. Its crowd-sourced library organizes everything, and the visuals on this launcher are, quite frankly, stunning. Including instruction manuals for the emulators, it's a super-friendly and easy-to-use package. Even if you aren't into emulators, it can store your Steam library, too. ***www.launchbox-app.com***

EarTrumpet's simplicity is what makes it so easy to quickly adjust your sound outputs.

23 Pin Steam

Everyone wants to make their PC aesthetically pleasing and effective, right? Well, here's one for your Steam games. As the name suggests, it enables you to pin your Steam titles to your Start menu with cool-looking tiles. Compared to standard icons, these visually rich tiles add detailed artwork to your Start menu, making it much easier to find and organize your games while improving the look of your PC. ***www.microsoft.com***

24 Discord

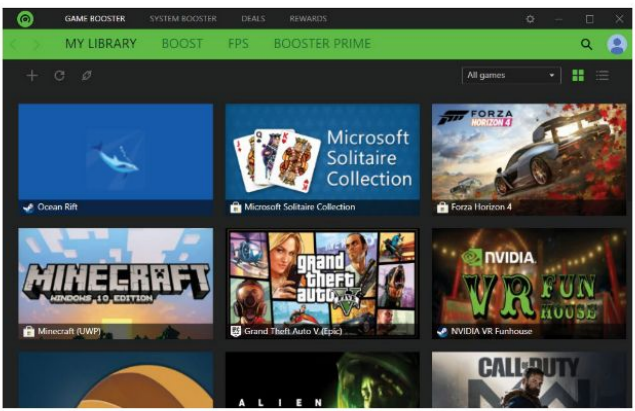
You have to be living under a rock if you haven't heard of Discord; this free communication app was bound to feature on our list. Although it has all sorts of uses, it can facilitate any sort of online chat, from VoIP to text to video, making it essential for gamers who want to hang out online with their pals. Its simplicity makes it a breeze to use, and for gamers, communication is key, so install this if you haven't already. ***www.discord.com***

25 GeForce Experience

Calling all Nvidia GeForce GTX users: You need this app. This free software is a great graphics card manager. It keeps your drivers up to date and optimizes game settings for better performance. You can also use GeForce Experience to share exciting in-game moments with pals. ***www.nvidia.com***

26 MSI Afterburner

Designed to push your Nvidia or AMD graphics card to the limit, MSI's Afterburner is a great tool for



Cortex displays your library with large artwork, for a simple yet effective UI.

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overclockers as it focuses on clock speed and video memory, enabling you to get better frame rates by increasing voltages and clock speeds, unlocking your GPU's potential. Make sure you have more than adequate cooling, though; the last thing you want is a fried GPU for breakfast, especially in this climate. ***www.msi.com***

27 SuperF4

We all know the pain of being stuck in a game when everything seems to crawl up and die. Your game freezes and you're forced to quit. Alt-F4 should do the trick, but this isn't always the case; Windows only asks the program to quit, and lets it decide for itself what to do. SuperF4, however, kills the foreground program when you press Ctrl-Alt-F4, or you can press Win-F4, then click the window with your mouse cursor. Straightforward but essential for those infuriating times when your PC just doesn't listen. ***https://stefansundin.github.io/superf4/***

28 GameSave Manager

As the name suggests, GameSave Manager's purpose is pretty simple: It enables you to automatically back up all your game save files at once and restore them. It also offers scheduled backups, and can tie in with cloud services such as Dropbox. If you're paranoid about game saves vanishing into thin air, GameSave Manager could be your golden ticket out of the missing or corrupt file abyss. ***www.gamesave-manager.com***

Take control of your graphics card with MSI Afterburner—just don't grill it.

Dusk II is one of *CS: GO's* most popular maps to get its own mode.

ESSENTIAL FREE GAMES

29 Call of Duty: Warzone

We mentioned it in the intro, so there's no shock that it features in our list. The bottom line here is that you get the same *Call of Duty* quality we all know and love, but for free. Of course, you only get the battle royale mode, not the campaign or standard online features, but battle royales are taking over, and the *COD* franchise sure knows a thing or two about producing a solid visually brilliant first-person shooter. Put two and two together and you have a great free game. ***www.callofduty.com/warzone***

30 Counter-Strike: Global Offensive

CS: GO has been popular for years, and by the looks of things, it's not going anywhere soon. At some point, you're bound to have played or watched it, and now it's free on Steam. For the uninitiated, it's an online team-based shooter; if you want to play casually with friends, you can, if you want a high-intensity competitive experience, you can have that, too. *CS: GO* works across all sorts of performance levels, so is a very accessible PC game. ***http://store.steampowered.com***

31 Old School RuneScape

If you love *RuneScape* and need to fill the nostalgia void, *Old School RuneScape* should do the trick. After a poll to revive it received over 50,000 votes, a separate older version of the already massive *RuneScape* was released in February 2013 to subscribers. By 2015, it was free to the public. It's one of the best retro MMORPGs to date—check it out now. ***https://oldschool.runescape.com***

32 Fortnite

Although you might be sick to death of this game, you can't deny its mass popularity, competitive nature, and attractive bright art style. It's certainly not going away anytime soon, and it continues to bring huge amounts of traction to gaming. Its building capability, paired with shooting and bringing the battle royale game mode to the forefront, are what sets this game apart, and why it continues to be one of the best free games on the market. If you want to hop online with your buddies, it's a great place to have a laugh, but also somewhere you can get carried away in its intense competitive underside, too. ***www.epicgames.com***

33 War Thunder

War Thunder was first announced back in 2011, with its worldwide release falling in 2013, and since then it has been one of the most prominent vehicular combat multiplayer games available. Its main focus is on richly detailed aviation war battles, with over 1,900 aircraft, ground vehicles, and warships to immerse yourself in. The graphics are stunning when running on full settings, and you can't ask for more when it comes to a completely free MMO. ***http://store.steampowered.com***

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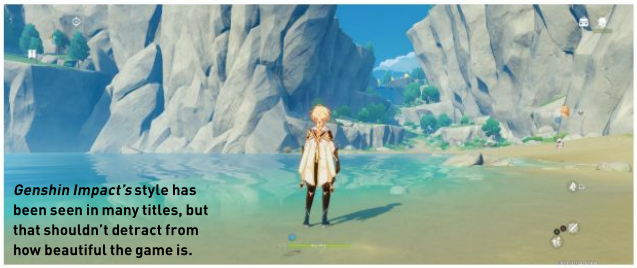

***Genshin Impact's* style has been seen in many titles, but that shouldn't detract from how beautiful the game is.**

34 DOTA 2

A top-down arena battle game that's almost certainly one of the best-known MOBA games to date, *DOTA 2* essentially spawned from a mod for *Warhammer III: Reign of Chaos*, but it's made a name for itself, especially in the esports scene. It was developed by Valve, with major involvement from the original creator of *DOTA*. If you're into real-time strategy and tower defense games, this MOBA is a brilliant free addition to your arsenal. ***http://store.steampowered.com***

35 Destiny 2

Closely following the construction of an open-world game, you can wander freely around this gorgeous game, either to explore every nook of the map or find quests to complete the campaign. The mythical sci-fi-inspired world is captivating, with its shared-world-style multiplayer. There are elements of PvE and PvP throughout, and with a triple-A FPS RPG like this costing nothing, it's worth giving it a go. ***http://store.steampowered.com***

36 RaceRoom Racing Experience

RaceRoom is one of our favorite car simulators. Its addictive yet realistic gameplay is a great example of what you can get from a free game. It's not quite full-fledged, like the paid alternatives, but the visuals are still stunning. *RaceRoom* is home to official race series such as DTM, WTCR, the WTCC, and ADAC GT Masters. If you want to race like a professional, jump into the driver's seat right here. ***http://store.steampowered.com***

37 The House in the Woods

Why not throw a horror title into the mix? If you've seen *The Blair Witch Project* and weren't scared enough (props to you), try out this game, then see how you feel. The story sees you out on a camping trip in the deep forest, when your friend vanishes during the night. You step away to investigate, but then you get lost, too. Classic scenario, but you'll certainly get the chills here. Whether you want to freak out your pals or enjoy the adrenaline that horror games give you, *The House in the Woods* is sure to satisfy. ***www.itch.io***

38 Genshin Impact

What you get here is a stunning open-world experience that uses elemental magic, character switching, and great brawls to draw you in. Visually, this fantasy adventure draws inspiration from the likes of *Breath of the Wild,* but we view that as nothing but a positive. There are tons of resources to collect, craft, and cook with, plus mini-bosses to fight and puzzles to complete, so *Genshin Impact* will still keep you on your toes even when you aren't following the campaign mode. ***https://genshin.mihoyo.com/en***

***War Thunder* invites you to buckle up and head for the skies in a high-paced battle game.**

CREATIVITY & PRODUCTIVITY

39 Adobe Photoshop Express

The Express edition of Adobe's world-famous photo-editing software is a free-to-use lightweight version. If you don't need the full version of Photoshop or don't want to pay the monthly fees (like many of us), this offers the same Adobe quality in a smaller package. It gives you all the basic features you need to edit pictures quickly. ***www.microsoft.com***

40 Blender

Fancy making 3D models for free? Then Blender has got you covered. With this incredible software, you can design and make models using a wide range of available tools. You can then go on to animate and motion-track the models you've created. The only real limit is your imagination. It can even act as a video editor or a 2D animation suite—combined with its amazing rendering engine, it all makes for a fabulous free tool. ***www.blender.org***

41 DaVinci Resolve 17

For a while, this program has been one of the best color graders on the market, but it's now a full-fledged video editing suite, too. It's been used for many large commercial projects, and you can check them out for yourself on the DaVinci website. If you are just beginning to dip your toe into video editing, or perhaps you already use other programs, such as Adobe's Premiere Pro or Sony Vegas, we recommend you take it for a spin—it's free, after all. ***www.blackmagicdesign.com***

42 LibreOffice

If you only use the basic features of Microsoft Office, LibreOffice is a great alternative that checks most of the boxes, but without the associated price tag. It's certainly not as feature-rich as Microsoft's flagship, but for creating most day-to-day documents, this suite should be able to produce what you need. It has alternatives for Word, Excel, PowerPoint, and more—not bad. ***www.libreoffice.org***

43 HandBrake

A little different from your traditional hand-operated stopping device, HandBrake is an open-source, free-to-use video converter. It's a must-have for video editors, because it's both powerful and easy to use. HandBrake

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converts video files into different formats, can be used for opening files of a random codec, or to make files more universally accessible. Free, easy, and obscurely named, we love it. It's also a handy benchmark tool, too. ***www.handbrake.fr***

44 Audacity

If you need to record your voice, whether that be from voiceover dubs, voice memos, video recording, or even if you want to kickstart a career in opera, Audacity is a superb free audio recording program. You can record, trim, add effects, re-organize, fade in and out, and much more. For audiophiles and microphone fanatics, this is an excellent choice, and a perfect alternative to Adobe Audition, albeit a little slimmed down. ***www.audacityteam.org***

45 Fresh Paint

Microsoft's Fresh Paint gives you a canvas on which to unleash your inner Picasso—well, you can attempt to, at least. It's a painting app with plenty of great tools for all sorts of artists. You can even transform pictures into paintings. It's the type of program where you can dabble a bit when the creative urge takes you, or spend hours using it to create a masterpiece. ***www.microsoft.com***

46 GIMP

This community-driven and developed image editor was bound to make an appearance here. Although it will never reach the same heights as its heavyweight rival Adobe Photoshop, GIMP has a strong foothold in the photo manipulation market, and its free price tag has a big role to play in that. It provides you with the right tools to get the job done, whether that be for graphic design, illustration, photography, or just messing around. ***www.gimp.org***

Plex's interface is neat, easy to follow, and supports great artwork .

47 FocusWriter

One of the biggest issues faced when trying to get a new writing project of the ground is the distractions that come along when working on your PC. We can definitely vouch for this one. FocusWriter helps you to stay in the zone with your writing by eliminating all these distractions. Its writing environment is light, distraction-free, and simple. It utilizes a hideaway interface that you access by moving your mouse to the edge of the screen. It's very basic, but definitely gets the job done. ***https://gottcode.org/focuswriter/***

Handbrake makes video converting simple, thanks to its easy-to-follow layout.

ENTERTAINMENT

48 Plex

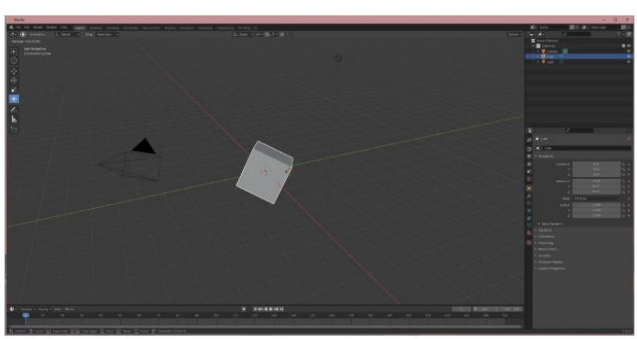
A great hub for all of your downloaded video files. If you have a massive database full of (legally owned) TV shows, movies, and documentaries, you can store them all in Plex. It's a media server that enables you to stream your files to your other devices. The interface is very tidy and designed to work effectively, organizing your files with the appropriate artwork. You can find the Plex app on all sorts of devices, such as the Apple App Store, Google Play, and even your games consoles. ***https://www.plex.tv***

49 Spotify

You'd have to be living under a rock, next to a needle wedged between 25 haystacks if you haven't heard of Spotify already. Since its launch, the music streaming service has pretty much taken over the way we listen to music. Spotify's free plan gives you access to an incredibly vast online library, and if you can ignore the occasional advertisements and don't want to download songs, this fulfills that need for instant music listening, anytime, anywhere (Wi-Fi signal permitting). ***www.spotify.com***

50 Steam

Pretty much the first thing you download after Chrome when you get a new gaming PC, right? Steam is the most reliable source of PC games out there—with a huge library, pretty much any game you can think of will be available via Steam. Its interface is engraved into most gamers' brains, and if it isn't engraved into yours, you don't have enough free time. Steam is an absolutely essential tool for any PC gamer. ***https://store.steampowered.com***


At first glance, Blender can look a little confusing, but with a little practice and patience, you'll realize how many incredible features this free software offers.

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Print, Build, & Wire Your Own Keyboard

ALL YOU NEED TO KNOW TO BUILD YOUR OWN 3D-PRINTED, MECHANICAL, ERGONOMIC KEYBOARD

Everyone who uses a computer uses a keyboard. The difference is, some people are happy with a $5 membrane board, some are happy with a $100-150 mechanical board. Then you have the enthusiasts.

There's never been a better time to be in the latter two categories. The mechanical keyboard space has never been so inclusive of end users and enthusiasts. Five to 10 years ago, anything smaller than a TKL board meant you were entering the enthusiast space. You'd be buying an HHKB, Ducky, Vortex/POK3R, or similar. Today, these names are far more popular, and many purist keyboard enthusiasts regard some of them as entry level. But they played a big part in shaping off-the-shelf boards.

Nowadays, all the top brands offer a 60-percent keyboard. Companies such as Glorious have taken it a step further by making hot-swappable boards more accessible. But how can we go even further? How about building a keyboard from scratch? Printing our own case, with custom wiring, flashing it ourselves, then crossing our fingers, and hoping it works. We like that idea.

Of course, this is *Maximum PC*. We're not going to go the easy route and build a 60 percent, TKL, or even a full-size board. Heck, if we did that, we might still have a full head of hair after the coding process. Instead, we're building a split keyboard. A Dactyl Manuform, to be exact. A parameterized, concave, columnar, ergonomic board. And we explain how you can, too. –DAVE ALCOCK

Building the Manuform Dactyl

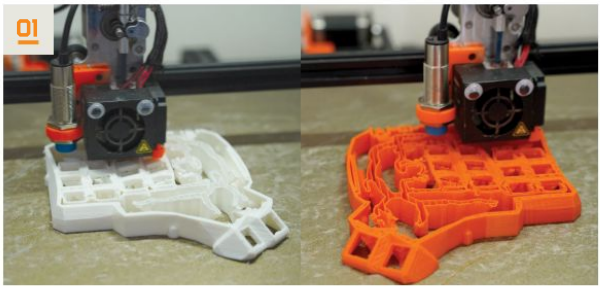
WHAT YOU NEED

PARTS

- **Keyboard case**
- **Keyboard case bottom**
- (2x) **Pro Micro controllers**
- (2x) **TRS/TRSS ports**
- (10x) **Brass thread inserts**
- (64x) **1N4148** (or similar) **switching signal diodes**
- (64x) **Cherry MX switches**
- (3 feet) **Wire**
- **TRS cable**

TOOL LIST

- **Soldering iron**
- **Wire strippers**
- **Phillips screwdriver**
- **Side cutters**



1 PRINT THE CASE

The first part of the build is simply printing out the case. The model is approximately 6 x 7 x 2 inches, so it will fit on most popular FDM printers with a bed over this size. We have access to a few 3D printers, one of which has a 20 x 20 x 20-inch bed, so we used that. With supports each side, it took around two days for each half to print. This time could have been reduced by having fewer walls and less infill, but we wanted to make sure that everything was as solid as possible. We used four walls and 30-percent infill. In total, we used just under 0.7lb of filament. The filament cost us $22 for 2.2lb, making the price of the case $7, not including the few cents of electricity we used. We also printed out a couple of wrist rests at the same time.

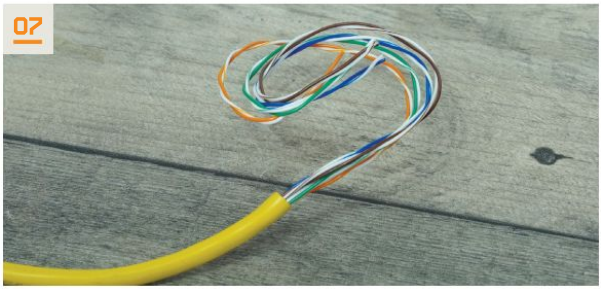
2 TIDY THINGS UP

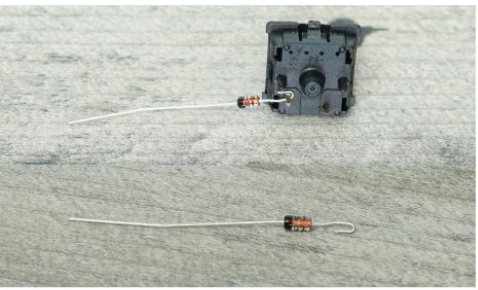
Once the prints were completed, we needed to remove the supports. The free 3D file that we'd downloaded to use for our prints had small clips that were supposed to help with cable management. They were horrible, however, and would just snap off while they got tangled up with the supports, and then also got in the way when soldering. That being the case, we simply used some cutters to chop these off so that the inside was clear. This way, we can just keep the wiring tight and neat, without having to worry ourselves about cable management.

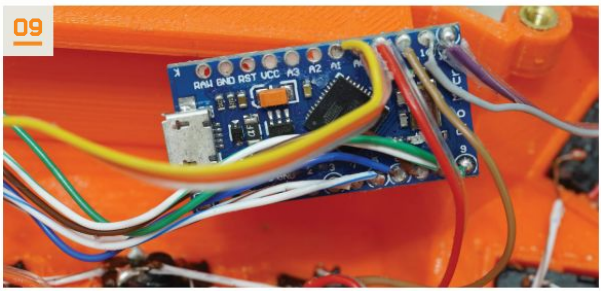
The cases are 3D printed, of course, so they are not perfect. We could sand them down, use filler, and then paint them, but to be honest, we actually like the rustic look a little bit more. The keyboard is obviously home-made, and if everything looked too perfect, we wouldn't get the usual "Wow, did you make this?!" questions we crave so much.

3 ADD THE INSERTS

Once the two case halves were completed, we wanted to make sure it was easy to attach the bottom half to the top. To do this, we used threaded brass inserts. These ones are M3, which enabled us to use spare screws from a PC case that we'd found. To get the brass inserts into the pre-determined holes, we used a soldering iron and a razor blade. We placed an insert into the hole, then put the tip of the iron into the threaded insert, and pushed while the heat melted the plastic. To stop the insert







from coming back out when we removed the soldering iron, we used a razor blade. This meant that it would stay flush with the rest of the case. Once the plastic around the insert cools down, it grips on to the outer contours of the insert, and holds it in place. Magic.

Next, the switches!

4 SLOT IN THE SWITCHES

For this version of the Dactyl, Cherry MX-style switches fit perfectly. Kailh-style switches would fit, too, but they're a bit more of a squeeze, and you would probably have to use glue or something similar to keep them from popping out. We decided to use Cherry MX switches—one of our favorites, in fact, the Cherry MX Greens. These switches are very tactile, with a rather loud click, perfect to use in the office to annoy any colleagues who may be working in the vicinity.

Inserting all the switches in the case is very easy. It's just a case of pushing them into the holes; the ridges on the inner edges of the holes clip on to the switches nicely. When choosing your switches, it doesn't matter if they're plate-mount or PCB-mount, because once they're all in place, it makes no difference in this application. If you do get PCB-mount, you can cut the PCB-mount plastic pins off to give you more room for the wiring.

5 PREPARE THE DIODES

Soldering the diodes to the switches is the next step. It's really important for the diodes to be soldered in the correct orientation. Diodes are there to allow the current to flow one way, but not the other. This enables the controller to figure out exactly which switch you pressed, because it knows where the signal stopped. The switches are laid out in rows and columns, and by using diodes, it is like giving each switch a grid reference, which equates to knowing which key has been pressed. The diode needs to have the black end facing away from the switch. It is easiest to solder the diode directly to the pin, and even easier if you make a hook to allow the diode to wrap around the switch pin before adding flux and solder.

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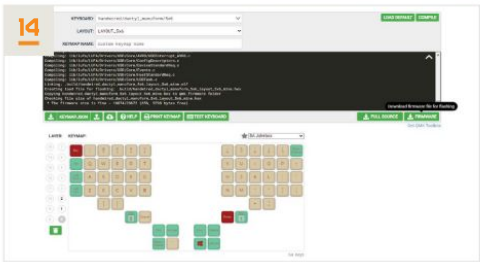
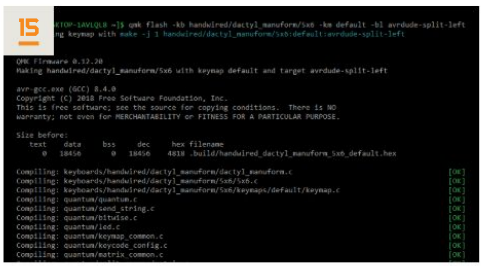




6 SOLDERING ON

Put the diode on the pins closest to the controller, because it makes it easier to route the cables. Once the diodes are connected, you can then solder them in series, so that you will be left with one end per row closest to the controller ready to solder. For our keyboard, this means six wires for the rows.

7 ACQUIRE SOME WIRE

We're doing the columns next. For this, we need some wire. We acquired a spare Ethernet cable that was carelessly left hanging from the back of this writer's PC. We cut off the end and stripped the outer insulation to reveal a whole bunch of wires. This is perfect for this application, because it's thin enough to be worked with and is more than ample to carry the low voltage. It also has eight different colors, so you can color-code the columns easily.

8 STRIP SEARCH

Measure the wire against the switches, so you can figure out where the insulation needs to be removed, then use a pair of wire strippers to remove sections of the insulation. This allows for the wire to be soldered to the switches, while keeping enough insulation on the wire to prevent any short circuits. You need one wire per column, which results in six more wires. Solder the switches in series again, making things rather neat and tidy, even with our amateur soldering.

9 MICROCONTROLLER OPTIONS

We're going to solder the microcontroller next. You need two controllers for a split keyboard—one for each side of the board. If you are building a standard keyboard, macro board, or numpad, you only need one. Pro Micros are ATmega32u4 8-bit microcontrollers with an integrated USB controller, and are perfect for this kind of application. We are using some cheap clones from Amazon, which were $18 for three, making them $6 each—bargain. The downside to these clones is that you need to install USB drivers for them before they work correctly. With some other controllers, you won't need to do this. Using the pinout (pg. 45), we soldered the rows and columns into the correct points on the Pro Micro.

10 WIRING DONE!

Both sides use the same pinout, but the wiring is mirrored. Once you have finished soldering and slid the controllers into their little holders, it should look something like the image (top-left).

11 BOTTOM BUSINESS

As we have access to a laser cutter, we decided to make the bottom of the plate out of 3mm

© QMK CONFIGURATOR

clear acrylic. This meant that we could see all of the internal wiring, and show off the fact that we made the keyboard ourselves. We countersunk the holes and added some little rubber feet.

12 CREATE A CABLE

We made a quick TRS cable with a couple of connectors, a borrowed micro-USB cable, and some sleeving that we happened to have left over from our sleeving feature to finish the build. We made it match the color scheme and ensured it was just long enough for the keyboard to sit comfortably on the desk without disconnecting. We then added some blank keycaps to finish the look.

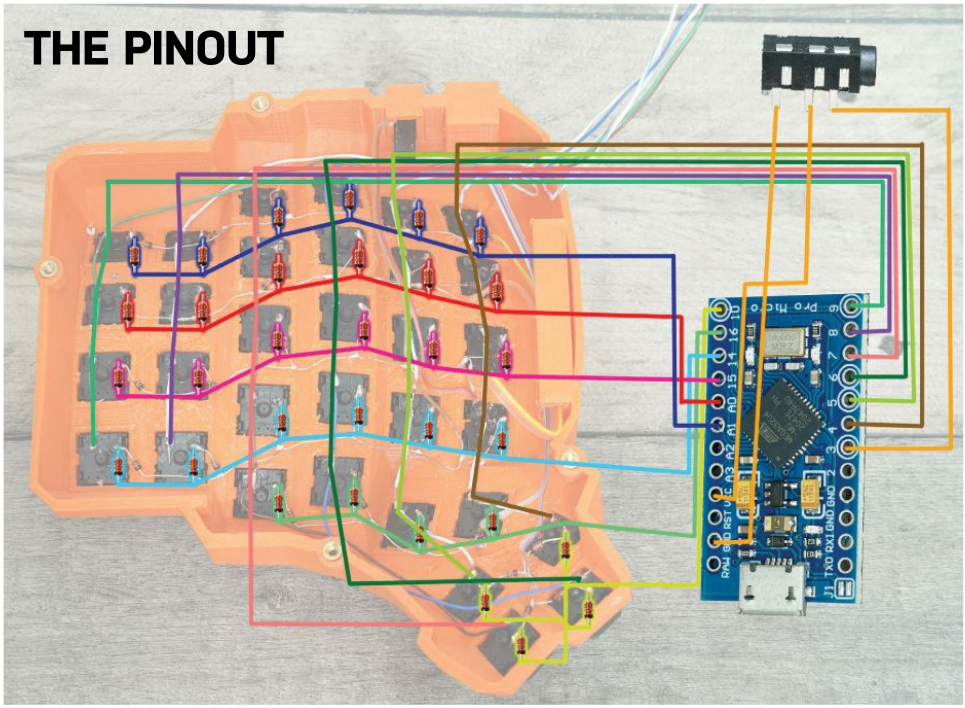
13 FLASH POINT

Now the physical side of the keyboard is complete, it is time to flash the microcontrollers, so that we can actually use our new board. We thought this part was going to be easy, because the QMK software project (https://qmk.fm) has released a nifty program known as the QMK Toolbox, which usually makes things simpler, as it already has predetermined open-source firmware layouts for custom boards like ours, including handwired Dactyls. But alas, things didn't work quite as intended.

The problem is fairly elementary. Some clones and Pro Micro controllers currently have a Schottky diode in them, which allows too much voltage to leak backward to the VBUS. This means that both controllers think that they are plugged in, even though only one is. In turn, this confuses the controllers, and makes them believe that they are both the primary controller, when in fact one needs to be the primary and the other the secondary controller.

14 PROBLEM SORTED

To fix this issue, we had to flash the controller using a slightly different method from the one we'd originally planned to use. First, we made the file using the website (http://bit.ly/MPCQMKConfig). We then compiled and downloaded the file, installed QMK MSYS (http://bit.ly/MPCMSYS), and then ran the QMK Setup command. This means we are now able to flash the keyboard. Before doing this, though, we went to the ¨config.qmk¨ file and opened it with Notepad++. You need a program that supports Unix line endings—this works, and it has the added bonus of being free. Once we open the config file, we add this single line: `#define SPLIT_USB_DETECT`. This fixes the problem that we outlined above. It took far too long for us to figure this out, though, and to be honest was far too simple a fix.



This is the pinout we made, which enabled us to wire the Dactyl. Each diode shows the orientation and also shows where to wire each column and row on the Pro Micro. The TRS port is wired to the 3, VCC, and GND terminals; these are the same color as it doesn't matter in which order these are wired, as long as they are done the same on both sides.

15 FLASH THE FILES

Now we're ready to flash the files through QMK MSYS. To do this, we connect the primary (left side) keyboard to the secondary part (right side) using the TRS cable, then plug a micro-USB cable into the left side. Run the following command:

```
qmk flash -kb handwired/dactyl_
manuform/5x6 -km default -bl avrdude-
split-left
```

Depending where the file is saved, the command changes. Reset the controller by shorting the RST and GND terminals on the Pro Micro. QMK MSYS then flashes the left side. Remove the micro-USB cable, but keep the TRS cable in place. Plug the micro-USB into the right side and run:

```
qmk flash -kb handwired/dactyl_
manuform/5x6 -km default -bl avrdude-
split-right
```

Reset the microcontroller again and wait for it to finish. Once it is finished, you plug the micro-USB back into the primary side, and you should be good to go.

Although flashing sounds easy enough, it does take a lot of research, depending on the board and layout. However, if you are confused at all, visit the QMK Discord server, and speak to the people in the Help section. They are extremely helpful, and gave us some pointers when we were struggling to flash the keyboard for a few days due to an issue that we had never seen previously.

16 CRAZY KEYBOARD

That's the keyboard done and dusted. Now we just have to spend a few months learning how to use it! The Manuform Dactyl is supposed to be very comfortable to use and can increase typing speed while staying ergonomic. Only time will tell if this is true or not, but one thing is for sure: It looks amazing.

PRICES

PARTS	STREET PRICE
Wire	Recycled/free
(10x) Brass inserts	$0.50
(2x) Pro Micro	$12
3D printer filament	$12
Switches	$60
Keycaps	$90
Diodes	$4
TRS cable	Recycled/free
TRS socket	$1
TRS jack plugs	$6
Acrylic	$10
Rubber feet	$1
TOTAL	$196.50

REACHING FOR THE STARS

A lot of the technology in your PC and your home originated in spaaaaaaace. *Ian Evenden* explains

THAT GOVERNMENT-FUNDED space agency your taxes support, **NASA**, doesn't just strap people to the top of a firework and aim them at the Moon. It doesn't even do that much now, but focuses on robotic exploration of Mars and crewing the International Space Station.

This is an agency, after all, that has three probes currently on their way out of the solar system, including the fastest human vehicle ever launched. It has put robots on Mars, probes on Venus (briefly), and sent more to investigate Mercury and the outer planets. Its latest Martian rover is a nuclear-powered laser-armed tank with a helicopter strapped to it.

Along the way, you'd expect it to pick up some neat new technology—and it has. Some of it has become so everyday that we almost no longer think of it, and some of it is in your PC. So, from the essential to the futuristic to the urban myths, here are the NASA inventions that have helped humanity the most.

© STF/AFP VIA BETTY IMAGES

The Apollo missions used several technologies that have subsequently entered everyday terrestrial life.

PORTABLE COMPUTERS

THE GUIDANCE COMPUTERS aboard space capsules were one thing, but it was only a matter of time before NASA wanted to take general-purpose computers into space. Beige boxes with CRT screens were too heavy and cumbersome to be shot into orbit aboard the Space Shuttle, so portable units were explored. This was the 1980s, though, and laptops were somewhat primitive.

In 1982, however, a company called GRiD developed the Compass, a computer that looks recognizably like a laptop. It was powered by an Intel 8086 CPU, with up to 512Kb of nonvolatile magnetic bubble memory (a defunct technology that was very durable, but tended to run a little hot), and things like disk drives available as peripherals. The casing was magnesium, and designed to act as a large heatsink for the CPU, memory, and the 320x240 plasma screen (which could be read in even the strongest sunlight, thanks to its bright orange text display). It came preloaded with office software, and cost the equivalent of $23,000 in today's money ($8,000 back in 1982).

NASA and the US military took no notice of the price tag, and enthusiastically embraced this little (10lb) machine, blasting it into orbit in 1983 and sending it into combat with paratroopers. Competitors such as the Osborne 1 or the Compaq Portable used CRT displays, and couldn't match the Compass's toughness (one reportedly survived the tragic 1986 Challenger disaster). NASA's only modifications to the hardware were a new cord to match the Shuttle's power system, bits of Velcro to hold it in place, and a fan to aid in cooling, as convection is tricky in space. On the software side, however, the newly rechristened SPOC (Shuttle Portable On-board Computer) received special graphical software to display the orbiter's position relative to Earth, and a backup copy of the re-entry program, just in case.

Thanks to its eye-watering price, the Compass became a symbol for affluence in many movies—you can see one in *Aliens, Wall Street,* and *Pulp Fiction.* If you want to see one today, go to the National Air and Space Museum in DC. As the first recognizable modern laptop, however, its influence is stronger than even its magnesium shell—the clamshell design, the flat screen, the storage with no moving parts, which is surely the precursor of today's SSDs.

Today, the Lenovo Thinkpad is the only certified computer for use on the US side of the ISS. There are over 80 of them up there, and they run Debian Linux. Some are connected to the ISS main computer as remote terminals for interacting with specific pieces of hardware. The Russians use Linux, too, although the specs of their systems are more mysterious, and are just referred to as "Russian Laptops."

SWITCHED-MODE POWER SUPPLY

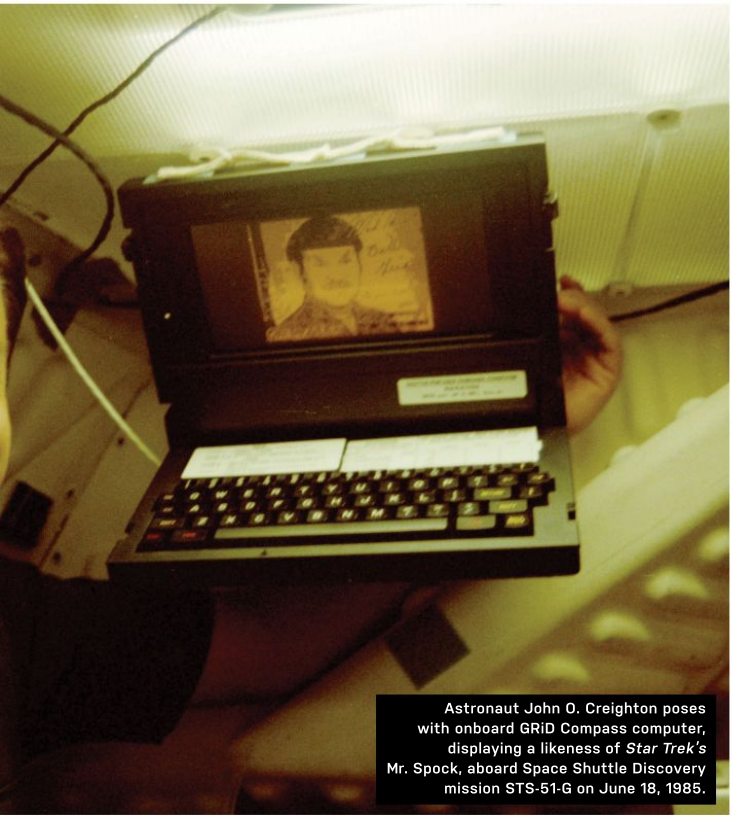
THE APOLLO GUIDANCE Computer is often held up as an example of how to do a great deal with very few resources. Running at about 2MHz, it had enough RAM to store 2,048 16-bit "words" and weighed 70lb. That, plus Isaac Newton and a few digits of pi, is all you need to fly three men into lunar orbit. What's equally interesting, however, is the way it was powered—the switched-mode power supply is the same type that provides the juice to your PC.

While earlier Gemini craft had been flown manually, Apollo capsules were computer-controlled except during landing. Each mission to the Moon carried two guidance computers—one in the command module and another in the lunar lander (except for Apollo 8, which didn't land), with further computers on the Saturn V rocket and in the launch abort system.

The guidance computers were built by MIT using some new technology—the "integrated circuit" made of silicon—and there was some debate over whether it would work, with a backup IBM system also built. The MIT system was triply redundant, and never experienced a hardware failure.

But back to its power supply. The MOSFET (metal oxide semiconductor field-effect transistor), invented at Bell Labs in 1959, became the most popular way of power switching, in which output voltage and current can

If it can power a computer that can guide a space rocket, it can sure as heck power your PC.



Astronaut John O. Creighton poses with onboard GRiD Compass computer, displaying a likeness of *Star Trek's* Mr. Spock, aboard Space Shuttle Discovery mission STS-51-G on June 18, 1985.

be changed by switching elements between different configurations inside the PSU. The advantage of this is greater efficiency, smaller size, lower weight, lower noise, and the use of a wider range of voltages and power frequencies than a linear regulator.

Switched-mode power supplies are everywhere now, from your PC to your cell phone charger, often with universal inputs so they can accept power inputs from around the world. The ATX standard offers 3.3V, 5V, and 12V rails, with a typical power output of over 500W, compared to the Apollo Guidance Computer's 4V (CPU) and 14V (memory and interface) at 55W.

© NASA, JOHAN/WIKIMEDIA

Memory Foam

If you've got a gaming chair, a wrist rest, a headset, or even a bed, you're probably familiar with memory foam. Also known as temper foam, it comes from a NASA contract in the 1970s aimed at improving seat cushioning under astronauts when they were being subjected to high G-forces. It also meant that seats no longer had to be customized for every astronaut's body shape.

Neil Armstrong, first man on the Moon, wearing an early Plantronics headset.

WIRELESS HEADSETS

WHAT LINKS Neil Armstrong as he stepped on the Moon with Boeing 747 pilots and every call-center worker ever? They all wear the same headset. It's barely changed in 50 years, and was originally designed to be implanted in an astronaut's helmet.

Pilots at the time wore bulky headsets, and in 1961, United Airlines invited proposals for an improved design. One pilot, Courtney Graham, teamed up with his friend Keith Larkin to create a new headset using transducers—a common hearing aid part that's also used in magnetic tape heads and electric guitar pickups.

Once their design had been accepted by United, Graham and Larking opened their own company—Pacific Plantronics—and set to work producing headsets for pilots and, a year later, air traffic controllers. Everyone, it turned out, wanted a better headset, and Plantronics was contacted by NASA to create something for the Mercury spacecraft. It took 11 days to put together a working headset design for space communications that also incorporated noise-canceling, and astronaut Wally Schirra was the first to use it on the Mercury-Atlas 8 mission, which orbited the Earth six times in 1962. The system would go on to be used in the Apollo Moon landings, and on to this day, while Plantronics now employs almost 4,000 people and has assets of over three billion dollars.

THE MOUSE

NASA CAN'T QUITE take full responsibility for the ubiquitous pointing devices—they date back to the late 1940s, and a British Navy fire control radar system that tracked incoming aircraft and calculated where to put missiles to best inconvenience them. The British classified it a state secret, but you can't keep a good concept down, and in the 1960s NASA was looking for new ways to interact with data on computer screens. Doug Engelbart, from the Stanford Research Institute, California, was busy inventing what we now call a GUI (graphical user interface)—computers with bitmapped screens, hypertext, collaborative tools, and pointing devices.

NASA was interested in the same things, and granted Engelbart funding to find the best pointer. The early mouse was a wooden device with two wheels underneath at 90 degrees to one another, and a rocking mechanism enabling you to draw straight lines. It was designed by Engelbart's lead engineer Bill English, and patented by Stanford in 1970 as an "X-Y Position Indicator For A Display System." The name "mouse" came about because of the cable, which looked like a tail, with the on-screen cursor known as a "bug," which didn't catch on.

"We were looking for the best—the most efficient—device," Engelbart said. "With NASA funding, the team developed a set of simple tasks, and timed a group of volunteers in doing those tasks with various devices. The mouse out-performed all the others. Devices like the light pen simply took too much time, by repeatedly requiring the user to pick up the pointer, and reach all the way to the screen."

Engelbart received no royalties, and Stanford licensed the tech to Apple for $40,000. The only problem NASA had with the mouse, according to Engelbart, was its tendency to float away in zero gravity.

Engelbart and English's first computer mouse prototype.

The Hubble Space Telescope is fitted with CCD sensors we'd consider low-resolution by today's standards, but it still takes stunning images.

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CAMERA SENSORS

TINY CAMERAS—in cell phones, webcams, GoPros and the like—have developed from NASA efforts to create compact, low-cost imaging systems.

The first type of digital imaging sensor was the CCD, or charge-coupled device. This operates in lines, with the data being passed from pixel to pixel until it reaches the edge of the chip, where it can be amplified and recorded. By replacing the CCD with a new sensor based on CMOS (complementary metal-oxide-semiconductor—the same tech in motherboard CMOS memory), every pixel can amplify its own charge, making the sensor more energy-efficient and sensitive. This is an active-pixel sensor (APS), and was first developed at Olympus in Japan, with Toshiba and Canon following. CCDs remained dominant, however.

NASA's Jet Propulsion Laboratory was able to make the first APS outside of Japan, with a team led by Eric Fossum. He left to found Photobit with his partner, Sabrina Kemeny, in 1995. It commercialized the APS tech, pushing it into areas such as endoscopy, DSLR cameras, cell phones and webcams. Photobit sensors appeared in Logitech and Intel products before the company was bought by Micron in 2001. With the arrival of HD video, most camera manufacturers switched to CMOS technology, as its low power consumption meant more pixels could be integrated without overheating or draining the batteries.

While CCDs are still used in astronomical imaging (in the Hubble Space Telescope, for example), new CMOS chips could chase them off completely. With high resolutions and low read noise, they're ideal for capturing faint, distant galaxies.

MRI and CAT scans

The digital signal processing tech developed by NASA to enhance pictures of the Moon in the Apollo program is used in MRIs and CAT scans. It also lives on in ACTIS, the Advanced Computed Tomography Inspection System, which produces scans of rocket engines or metal castings to identify flaws. It has also been used to examine T-rex fossils without removing them from the rock they're embedded in.

MYLAR

COAT SOME PLASTIC film (biaxially-oriented polyethylene terephthalate, to be precise) with a thin layer of aluminum, gold, or another metal, and you've got Mylar, a thin sheet that reflects 99 percent of light, including much of the infrared part of the spectrum. Add another layer of polyethylene, and you've got something that's puncture-resistant and impermeable to gases.

Its uses are myriad. It's in speakers, headphones, and mics. It's in keyboards. It's in floppy disks and cassettes, if you've got any hanging around. From pinball machines to the capacitors on your mobo to the silver blankets emergency services use, it's there. If you play banjo, it's there, too.

You'll also know it as the silver coating of the descent stage of the Apollo lunar module, or the wrapping for the Hubble Space Telescope. Its ability to insulate while being thin and light makes it ideal for spacecraft, which is why NASA developed it.

Echo 2 undergoes a stress test in a dirigible hangar, North Carolina, 1964.

Actually, its history goes back to the chemical companies DuPont, ICI, and Hoechst in the 1950s. They developed the BoPET film, and Kodak went on to use it as a backing for the 6,000-feet reels of film used on long-range U2 reconnaissance flights. NASA's input was the metallic coating—in 1960, it launched Project Echo, a passive communications satellite that was really a large balloon. The Mylar spheres left the atmosphere on top of a rocket, then inflated to 100 feet in diameter. They were passive, serving only to reflect the microwave transmissions beamed at them.

There was one problem with them. Because they were large and light, they were pushed by the solar wind, something NASA has been keen to take advantage of with its experimental technology demonstrator Sunjammer. Other space agencies are in on the idea, too, such as Japan with IKAROS: Huge sheets of Mylar that use the stream of energized particles expelled from the Sun as a means of propulsion.

Dealing with dust will be a major problem when humanity goes back to the Moon.

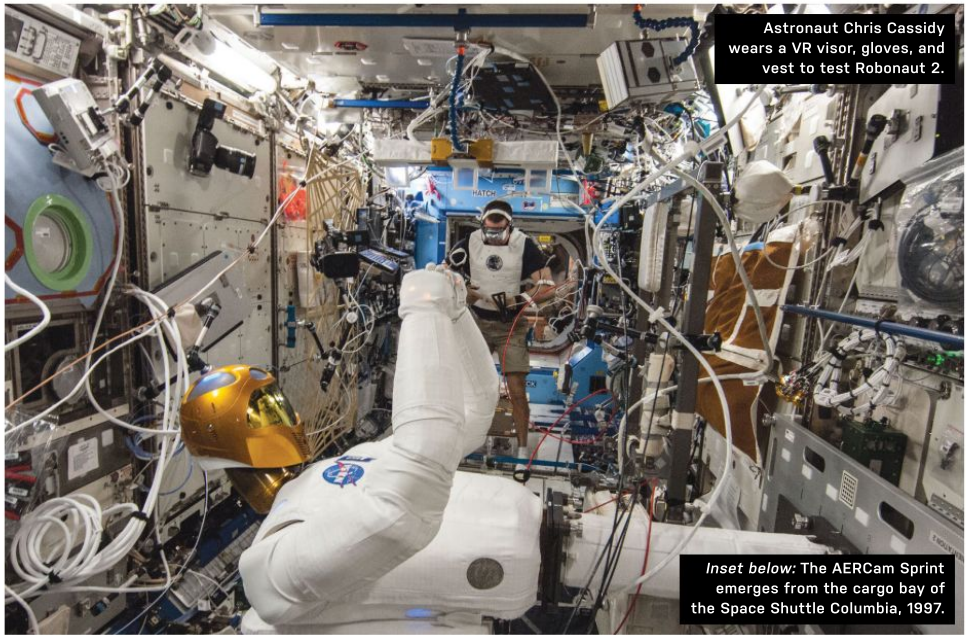
DUSTBUSTER

EVERY TIME you suck the dust out of your PC's case with a handheld vacuum cleaner, you're following in the footsteps of astronauts who collected samples from the Moon.

It all comes down to a cordless power drill designed for use on the Moon, which had to be able to drill into rocks yet consume the smallest amount of power possible. While most of the samples collected by astronauts were picked up from the surface, subsurface soil was also dug up from depths of up to 10 feet. As they didn't want to carry huge numbers of batteries around with them, the drills needed their own power source, and to be as small, light, and powerful as possible.

Black and Decker worked with NASA on the problem, eventually coming up with a computer program that optimized the design of a magnetized motor for minimal power consumption. All the R&D carried out was folded back into Black and Decker's product line, resulting in a range of cordless appliances, and leading to the launch of the Dustbuster in 1979. It sold a million in its first year, and more than 100 million since then.

Dust is a problem in space, so the tech came full circle when NASA put out a call to universities in 2019 asking for ideas for keeping abrasive Moon dust off surfaces and spacesuits. A team from the University of Colorado Boulder came up with a negatively charged electron beam which, when applied to dust in a vacuum, causes it to leap away from the surface it's sticking to. So, in 20 years, we'll be cleaning our PCs with electron beams.



Astronaut Chris Cassidy wears a VR visor, gloves, and vest to test Robonaut 2.

Inset below: The AERCam Sprint emerges from the cargo bay of the Space Shuttle Columbia, 1997.

VIRTUAL REALITY

THE 1980S were a good time for virtual reality. There was investment from games companies and the military, and a dream of a space station with a virtual environment, in which astronauts lay on couches and used VR to control robots to do all the work.

This didn't happen. The ISS isn't a gleaming white sci-fi utopia, but a cramped and occasionally leaky conglomeration of modules, nationalities, and technologies. The tech of the 1980s proved to be unsuited to the task—the helmets were too heavy, early touch interfaces didn't work, and computers were too slow to create what was needed.

Following a re-think, equipment such as the AERCam Sprint—a free-flying camera powered by nitrogen thrusters and enough battery for seven hours' flight—were steered using laptop screens rather than through a VR headset, but NASA's attempts to create a robot to work alongside astronauts have seen it collaborating with Sony. PlayStation VR was the platform for *Mighty Morphenaut,* a training game designed to help humans operate the Robonaut 2 robots, which look like a terrifying amalgam of Bishop from *Aliens* and a Cylon.

There have been teething problems, however, especially due to lag. "The hope is that by putting people in an environment where they can look around and move in ways that are much more intuitive than with a mouse and keyboard, it would require less training to understand how to operate the robot and enable quicker, more direct control of the motion," said Garrett Johnson, a software engineer at NASA's JPL, in a 2016 interview. "[With *Mighty Morphenaut]* we were able to explore a possible solution and … demonstrate the problems of operating with delayed communication. With time delay, anticipating the motion of a floating object makes it nearly impossible to interact, so further research might include ways to help users predict that kind of motion."

Scratch-resistant lenses

If your glasses or shades boast that they're scratch resistant, they probably have a NASA invention sprayed on them—a layer of diamond-like carbon that protects plastic lenses from scratches and also reduces friction, so water runs off them easily. It was originally developed to coat the visors of space helmets, and both the coating and the method of depositing it are NASA tech.

Invisible braces

If you've had teeth straightened using invisible braces, you've been wearing a NASA-developed ceramic originally made to help track missiles. Transparent polycrystalline alumina is stronger than steel, and was used to make the domes that cover radar installations. It's not the first time space tech has made its way into our mouths—some fillings use material developed for the heat-resistant tiles on the Shuttle.

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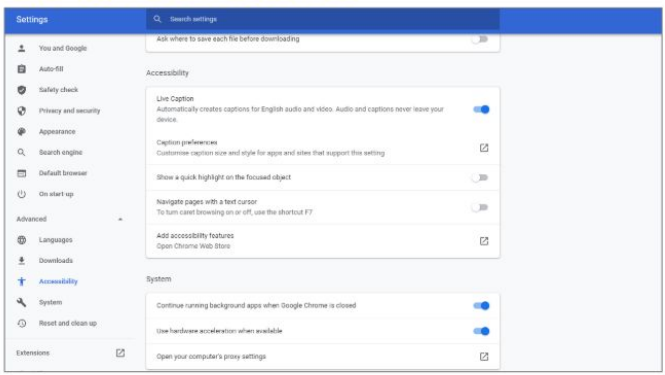
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

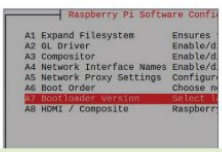
TIP OF THE MONTH



GOOGLE CHROME LIVE CAPTIONS

If you ever struggle to hear or understand an online video, you'll want to know about this. Using Chrome, head to the three dots at the top-right of the screen, and open up "Settings." Go to the "Advanced" section on the left, then head to the "Accessibility" menu. Here you should see a "Live Caption" option. Turn this on and you'll be able to see captions for any video, which appear in a pop-up window.

MAKE – USE – CREATE


Raspberry Pi Software Confi
A1 Expand Filesystem Ensures
A2 GL Driver Enable/d
A3 Compositor Enable/d
A4 Network Interface Names Enable/d
A5 Network Proxy Settings Configur
A6 Boot Order Choose
A7 Bootloader Version Select
A8 HDMI / Composite Raspberr

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66 Build an epic next-gen gaming machine

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SAM LEWIS
STAFF WRITER

SWAMPED BY TECH

As the months go on, it's clear that the tech world has completely engulfed me. Having previously always kept my nose in the technology sphere but only ever getting to experience a small part of it, this change has been colossal. Especially when trying out concepts such as VR and entering the audiophile abyss. With tech now filling my life, there comes an awful lot of efficiency—or laziness, depending on how you view it.

I try to make life easier by implementing technology wherever I can. The most recent and laziest example of which has to be my mini keyboard with built-in touchpad. Because I plug my laptop into my TV, it saves me moving every time I need to change anything—it's the ultimate couch-potato accessory. Being almost spud-sized and coming in at around $20, there's little not to like about it. Don't get me wrong, though—I'm certainly not writing this using it!

As far as audio tech goes, I have finally received some headphone DAC/amps, so I can fully make use of the many headphones I have in for testing. Paired with Tidal, it's only further increased the hours each day I spend listening to music. I'll take that as a win!

↘ submit your How To project idea to: comments@maximumpc.com

IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

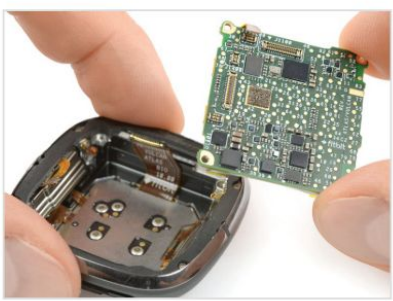
Fitbit Sense

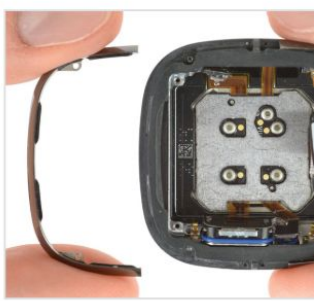
Torx screws and connectors attach the motherboard.

Even if you're handy with a soldering iron, everything is locked in with some serious adhesive.

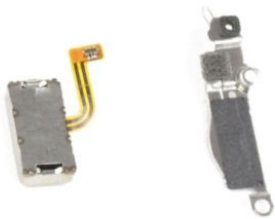
About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com.





Riddled with sensors and health features, the new Fitbit Sense is poised to rival the Apple Watch Series 6 as a health-focused wearable device.



Lots of heat and careful prying needed to open up this watch.

BACKGROUND

The new Fitbit Sense competes against the Apple Watch Series 6, but what happens when the Fitbit gets sick? Well, that's why we're here today—to determine how difficult the surgery will be.

MAJOR TECH SPECS

- 1.58-inch AMOLED screen
- 4GB internal storage
- A new ECG function as well as a skin temperature sensor, and the standard optical heart rate sensor
- Wi-Fi, NFC, Bluetooth 5.0, and built-in GPS
- Water resistant up to 50 meters
- Also part of the package are a gyroscope, altimeter, three-axis accelerometer, and ambient light sensor

KEY FINDINGS

- Like the Apple Watch, the Fitbit Sense's ingress protection means the very thin gap between the display and the housing of the watch is lined with adhesive. Even with a heat gun and extremely thin prying tools, it is difficult to get the display to budge. A semi-unprotected OLED display underneath the glass and booby trap cables near the edge add to the challenge. Though it is precariously placed, the display cable is long enough to allow us to lift the screen with ease once the hard part is done. Underneath we're greeted by a small bracket fastened with tiny T2 Torx screws covering the connectors we need to disconnect—no problem for our Pro Tech Toolkit.
- The motherboard doesn't come out alone—the battery hitches a ride, lightly adhered to its underside. The battery is a 1.02Wh (266 mAh @ 3.85V) cell, slightly less potent than the 1.17Wh cell of the Apple Watch Series 6, and a far cry from the 2.16Wh cell in the Xiaomi Watch. We get the Sense that this Fitbit is considerably less complex than any Apple Watch. That's good for these repairs—battery, board, and screen are all accessible within a few steps!
- Two more brackets tucked up against the sides of the housing keep a few more key components in place: loudspeaker and pressure sensor on one side, and a microphone, vibration motor, and pseudo-button on the other. Apart from the vibration motor, all of these components connect to the sensor board at the bottom of the housing and terminate in soldered connections. It's unlikely you'll be able to remove it without damaging something. The edge around the display features two separated metal brackets for reading your EDA levels (electrodermal activity) and taking that ECG.
- While the opening procedure is far from ideal, most of the critical components in this Fitbit are accessible and replaceable, and disassembly is very straightforward. Unfortunately, some components are integrated into the sensor board, which is fastened with permanent adhesive. Let's wrap up this quick teardown with a score....
- Repairability Score: 5 out of 10 (10 is easiest to repair). Watch bands are easily replaceable (though not standard issue). Standard screws are used prudently throughout the device. The display-first disassembly procedure means screen replacements require only a few steps, but those steps are difficult, and can easily damage the display. The battery is buried under the main board, but it can be disconnected immediately upon opening the watch, and is easy to remove once you get to it. Components underneath the battery aren't modular, and will be very difficult to remove because of their strong adhesive.

How to Edit RAW Images in Photoshop

YOU'LL NEED THIS

ADOBE PHOTOSHOP CC 2018 ONWARD
To view compatibility visit: https://helpx.adobe.com/photoshop/system-requirements.html.

WINDOWS 10
64-bit, version 1809 or later.

FOR THIS TUTORIAL, we're taking a look at working with RAW images within Photoshop. A RAW picture is usually minimally processed and uncompressed. When you shoot in RAW, your camera captures all of the sensor's data, resulting in super-detailed image files. Benefits of shooting in RAW include increased brightness, higher dynamic range, more colors in your images, and more scope to edit, because the files contain more information. Obviously, with a richer image, larger file sizes are to be expected, and image processing is required.

RAW photography is nowhere near as quick as pointing and shooting in JPEG format, but when you're shooting specific stills and need the best quality, RAW trumps JPEG. RAW file types alter between different devices, such as brands of cameras and phones. For example, Nikon cameras shoot in NEF, whereas Canon's RAW file formats are CR2 or CR3. On Android, they're called DNGs, which are a universal RAW format, while on Apple, they are called ProRAW files, which are fairly new. We'll explain how to take these files through Adobe's RAW processing software and into Photoshop, where you can get the most out of your shots. **–SAM LEWIS**

1 FIND A PHOTO

To start with, you need a RAW file. If you don't have one or would like to practice on some stock imagery, a good place to find RAW images is www.signatureedits.com. It has a large library of free-to-use files, perfect for this tutorial. You'll notice that the file sizes are larger than JPEGs—that's because they're uncompressed and still contain all the image's detail. Once you've decided which shot to use, rename the file to make life easier, right-click it, and open it with Photoshop. We've selected a stunning desert shot to edit.

›› You'll notice that when you open your image in Photoshop, another program pops up. Fear not, it's just Adobe Camera RAW [**Image A**]. This is Adobe's RAW processing software; it reads the RAW information, then you can edit things such as white balance or exposure, for example, in that RAW file. Afterward, the image opens in Photoshop. It may sound a little complex, but trust us, it's a breeze.

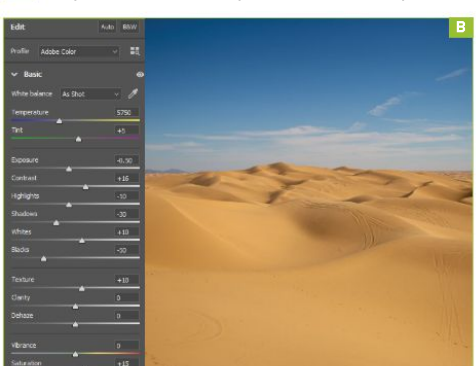
2 RAW POWER

Some of the steps that we'll go through in this tutorial have to be followed every time you use RAW files, but before we get to those crucial steps, we're going to look at why we need to edit the basics of the image here first, before heading into a project, and what features Adobe Camera RAW has to offer. When working with a RAW file, you have so much more data to play with. That includes a wider color range, a greater high dynamic range, wider white balance, further sharpness and noise adjustments, and more. In short, it gives us more control over the image, and that is exactly what you want when manipulating a photo.

›› When working within Adobe Camera RAW, you're editing the file directly, so you have more control than you would in Photoshop. Photoshop is where you would focus more on the visual effects; Adobe Camera RAW makes sure your starting image is as good as it can be. As you can see, some of Adobe Camera RAW's features are available straight away on the right-hand side. Under the "Basic" tab are the most fundamental settings, such as white balance, temperature, exposure, saturation, contrast, shadows, highlights, whites, and blacks, for instance. These sliders help bring some life into your image and give you a good strong start for your project.

3 TAKE YOUR TIME

For this image, we want to make a few edits to give it a cleaner, more detailed look. Before just diving straight to the sliders, analyze your shot and figure out what's not so great about it. Our image looks a



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JPEG VS. RAW

There are many benefits to both JPEG and RAW—and, of course, there are more than just these two file formats to choose from. JPEG is one of the most commonly used image file formats you can find. In simple terms, JPEG is compressed, while RAW is uncompressed, but what does that actually mean, and how does it affect an image?

Typically, JPEG is set as the default file format for still images on the majority of cameras. It utilizes lossy compression for storing and displaying digital images. Due to its compression efficiency, it's the most popular image file format. Most display devices and software have built-in capabilities enabling them to read and display JPEG pictures. The benefits include smaller file sizes (no need to explain why that's an advantage), faster write times, and a choice of compression. This enables you to choose between file size and image quality. There are also a few issues associated with JPEGs. Because they use a lossy compression algorithm, data is lost. This restricts how much you can edit a picture, and can result in visible pixelation and posterization issues in more compressed files. It is harder to recover data in a JPEG shot, so if your image is sharp, it will be more difficult to unsharpen. The same applies if your shot is over- or underexposed; it will be very difficult to rectify this, as JPEGs have a smaller dynamic range.

RAW files, on the other hand, are uncompressed. This means that there's lots of data to edit with, and they suffer far less from image-compression artifacts. One of the biggest advantages that RAW files have over JPEGs is a vastly greater color range. This gives you so much more scope to get your images exactly how you want them in the editing process. With this comes a much larger dynamic range, so for recovering data in an image, RAW is far superior to a JPEG. With this increase in data comes the inevitable elephant in the room, though: the elephant-sized files. RAW images are far larger than JPEGs, so unless you already have plenty of storage in your device, you may want to invest in that department if you are shooting in RAW format. Also, a RAW file must be processed and converted to a format such as JPEG to be viewed normally, which takes up more of your time when editing. Finally, a big issue with RAW images is the compatibility between different manufacturers. Brands such as Canon cannot read Nikon files, and vice versa. It can get tedious, and you need certain software to open up these files to edit.

Both formats clearly have pros and cons. What you need to work out is the type of photography you will be doing. If you are taking photography more lightly and capturing images purely for memories and fun, JPEGs will be more than sufficient. After all, bigger file sizes mean fewer pictures. On the other hand, if you're leaning more to the professional and commercial side of photography, RAW files give you so much more detail and scope to transform into great art. RAW images let you take control.

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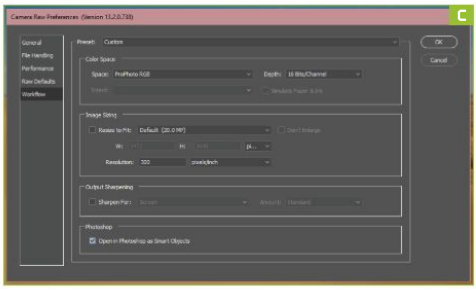


little faded and washed out, so we need to add some sharpness, structure, and warmth to bring it into life.

›› You can see how we added some warmth, detail, and quality to the shot using the sliders [**Image B**]. Adding saturation and reducing the shadows and highlights did the majority of this for us. Dropping the temperature seemed to get a better result than if we increased it, which made it look unrealistic. Take time with these adjustments and don't get carried away—it's easy to add too much to an image and make it look harsh. Compared to the original shot, it appears more detailed and richer. Thanks to the data that RAW images keep, you can achieve this while maintaining image quality.

4 BITS AND PIECES

Before properly heading into Photoshop, we have to do the most important stage. At the bottom of the window, there is an underlined piece of text detailing important information about the image. The text should end with the image's PPI number. When you click this, it opens another window called Camera Raw Preferences. Go to the left tab and open the "Workflow" menu. At the top, you can choose your color space—we're working digitally, so need to use an RGB space. We've selected "ProPhoto RGB," because it's the largest. To the side of that, we need to make sure the depth is 16 bits.

›› Finally, you should see a "Photoshop" option at the bottom. By default, this is unchecked; it's the option to open in Photoshop as a Smart Object. Make sure it's checked [**Image C**]. It enables you to open Adobe Camera RAW if you need to go back halfway through your project to alter the RAW file again. It gives better results than trying to edit over it using the standard Photoshop procedure. So, whatever you do to the Photoshop file, if it doesn't look right color-wise, you don't need to use countless undos—you can go into the Smart Object and edit the source from there.

5 READY FOR PHOTOSHOP

Click "OK," then at the bottom hit "Open Object." This converts your edited high-quality image into a Photoshop file. To check this is correct, go to the "Image" menu and click "Mode." It should have "RGB" selected, as well as "16 bits." Another place you can check to see if the color space has transferred over is in the "Edit" menu. Head there and click "Convert profile" toward the bottom of the drop-down—it should be the same as you chose in the RAW settings. This is the best way to start a project, as it enables you to make changes without ruining the original. Now you're set [**Image D**].

›› As you can see, the layer on the right has a slightly different thumbnail from a standard layer, because it's a Smart Object. When you double-click it, the Adobe Camera RAW program opens back up. Simple. To finish off this image, we want to clean up some of the sand tracks in the foreground. Using Photoshop's spot healing brush and the patch tool, we end up with a cleaner image that still retains lots of detail, and looks a lot richer than the original [**Image E**].

© ADOBE PHOTOSHOP

Run Windows on a Raspberry Pi 4

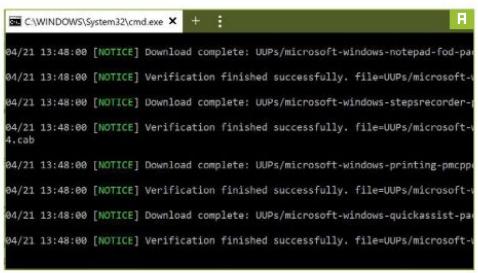
YOU'LL NEED THIS

RASPBERRY PI 4
We used the 8GB model. You also need an 8GB or greater microSD card, a wired Internet connection, and infinite patience.

THIS IS IT, the real deal. No tricks involving VPNs or virtualization. This is the ARM port of Windows 10 running natively on a Raspberry Pi 4. Slowly. Best of all, it kinda works. Even with an overclocked Pi, however, it's slow, bringing back memories of running Windows 7 on an Atom-powered netbook. It's not unusable, but it does come with problems. The main one is that the Pi's Wi-Fi doesn't work, so you need a compatible USB adapter or an Ethernet connection. It can be very crashy when you connect to the Internet, unless you follow our genius tip below.

So, you've got a wobbly OS on which you can only install a limited number of apps. Perhaps you'll have better luck with initial stability, or a Windows update will bring the Wi-Fi online.

It's what this represents, rather than what you can do with it, that's important. As we said when we reviewed the Pi port of Ubuntu, this makes the diminutive single board a computer you can use every day—the mainstream Raspberry Pi OS tries, but it's still stuck in 32-bit hell, and the 64-bit version has its issues—even if it is a few updates away from perfection. –IAN EVENDEN


C:\WINDOWS\System32\cmd.exe
04/21 13:48:00 [NOTICE] Download complete: UUPs/microsoft-windows-notepad-fod-pa
04/21 13:48:00 [NOTICE] Verification finished successfully. file=UUPs/microsoft-
04/21 13:48:00 [NOTICE] Download complete: UUPs/microsoft-windows-stepsrecorder-
04/21 13:48:00 [NOTICE] Verification finished successfully. file=UUPs/microsoft-
4.cab
04/21 13:48:00 [NOTICE] Download complete: UUPs/microsoft-windows-printing-pmcpp
04/21 13:48:00 [NOTICE] Verification finished successfully. file=UUPs/microsoft-
04/21 13:48:00 [NOTICE] Download complete: UUPs/microsoft-windows-quickassist-pa
04/21 13:48:00 [NOTICE] Verification finished successfully. file=UUPs/microsoft-

1 THE DOWNLOADS

On your main Windows machine, point a browser to https://uupdump.net and select the latest public release build for the ARM64 architecture. Don't let muscle memory guide you to x64; this is for the Pi, not your PC. We downloaded and installed Windows 10 version 2004, but after we did all that, we noticed that 20H2 was available, so you should go for that, or a newer build. Choose your language, and the version of Windows you want (we left both "Pro" and "Home" checked, and Home installed), then on the next screen, choose "Download and convert to ISO," and click "Create download package." This download is very small.

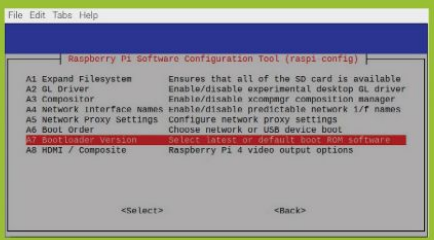
›› Extract the Zip file somewhere convenient, then run the "uup_download_windows.cmd" script file as an administrator—bypassing SmartScreen if necessary. This fires up Aria 2 [**Image A**], an open-source download utility that runs in the command line. This then handles the big download and build of the image files, and you'll see it working in a window. After a long wait, depending on the speed of your PC and your Internet connection, you'll end up with an ISO in the same folder.

›› Now head to https://www.worproject.ml/downloads and download the latest version of the Windows on Raspberry Imager. It was 2.01 for us; you might get a newer version. This works very much like the Raspberry Pi Imager, in that you point it to both your SD card and the ISO you just created, then sit back while it writes the OS to the card in a bootable fashion. There are some extra steps in this app, however, but it's all pretty self-explanatory. More waiting ensues. Eventually, you'll be prompted to press 0 to exit.

2 THE FIRST BOOT

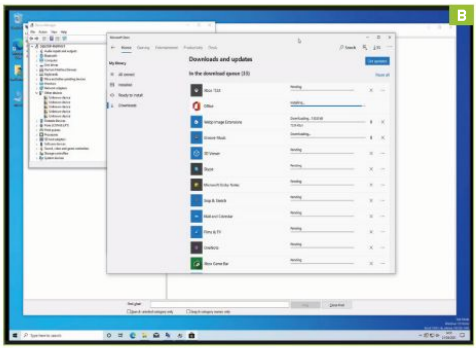
Once the card has been written to successfully, pop it out of your PC and into the card slot of your Pi. The first time it boots, make sure your Ethernet cable is unplugged to avoid a crash. It takes a long time, and looks like it's frozen, but persevere and eventually you get to the familiar Windows 10 setup screens. Don't connect it to a network, even if a miracle happens and you get a build of Windows with a working Wi-Fi driver. You're asked for a username and password, and eventually you find yourself on the blue desktop we all know and,

BOOTLOADER


File Edit Tabs Help
Raspberry Pi Software Configuration Tool (raspi-config)
A1 Expand Filesystem
A2 GL Driver
A3 Compositor
A4 Network Interface Names
A5 Network Proxy Settings
A6 Boot Order
A7 Bootloader Version
A8 HDMI / Composite
Ensures that all of the SD card is available
Enable/disable experimental desktop GL driver
Enable/disable xcompmgr composition manager
Enable/disable predictable network I/F names
Configure network proxy settings
Choose network or USB device boot
Select bootloader update behaviour
Raspberry Pi 4 video output options
<Select>
<Back>

If you want slightly better performance, try installing Windows on a USB-connected SSD and using that to boot the Pi from one of its USB 3 ports. After all, microSD cards are noted for their size and storage capacity, not their data transfer speeds. In the Windows on Raspberry imaging software, just pick the SSD in place of the SD card, but you may need to update your Pi's bootloader. This should be handled automatically as you do OS updates, but you can do it manually with the Raspberry Pi Configuration Utility.

Open a Terminal Window and type `sudo raspi-config` then scroll down to "Advanced Options." Choose this, and scroll down to "A7 Bootloader Version." Select this, then choose "E1 Latest" from the next screen. Hit "OK" and you'll need to reboot your Pi for it to take effect.



well, know [Image B]. Incidentally, if anyone has developed a workable method for telling microSD cards apart, please let us know. They're too small to write on, and we've developed a large collection, all of which look largely the same. Our memory isn't what it used to be.

3 ON WITH THE TUTORIAL

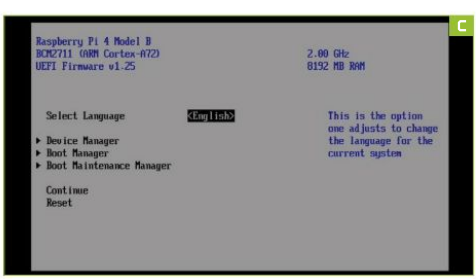
Booting to the desktop proves it works. You can try, at this point, to plug in an Ethernet cable to see what happens. For us, it led to a blue screen, with an error code that suggests a hardware or memory corruption error. Upon rebooting, we hammered the Escape key to get into the EUFI firmware [Image C]. The firmware limits the Pi to 3GB of RAM by default, so to access the full 8GB in our Pi 4, we open up the config options in "Device Manager → Raspberry Pi Configuration → Advanced Configuration." Change "Limit RAM to 3GB" to "Disabled."

4 FIX THE CRASH!

Here's how we fixed the crashing issue when we connected to the Internet. Keep the Pi limited to 3GB of RAM, and boot from cold with the Ethernet cable already connected. That's it. Only then, once we were happy it was stable online, did we enable the full 8GB RAM from the config menu. Doing things in this order left us with a stable, if slow, operating system that was recognizably Windows 10.

›› Being online allowed us to run Windows Update, which downloaded the 20H2 update we should have installed in the first place. Oddly, we weren't prompted to reboot once the new version update had downloaded through Windows Update, so we did it ourselves. The process this triggered took an unbelievably long time, and when we got back to the desktop, nothing had changed. We were still on build 2004. Two more restarts using "Restart now" in the Windows Update Settings applet had no effect; only popping up the Start menu and selecting "Update and restart" from the "Power" options worked, bringing up 20H2-specific setup options such as "Windows Hello" before the desktop appeared, but not clearing the need to restart in the Windows Update applet.

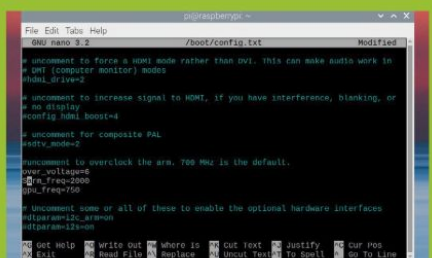
›› This is the risk you take with running unfinished software on hardware it's not optimized for. Opening the Device Manager, for example, brings up at least five "unknown devices" among the Pi's limited range of hardware. We tested things like the USB ports, and found them all to be working, and popped open the Windows Store for updates.



5 SOFTWARE

You're not going to be able to run x64 software on the Pi's ARM processor, though you can install 32-bit versions of x86 apps. This goes for things such as Chrome and GIMP (though watching the latter start up was painful). Microsoft's Office apps come with the Windows ISO, if you've got a subscription, and the Microsoft Store is available. Edge isn't such a bad browser these days, and we found the version included with 20H2 to be much faster than 32-bit Chrome.

OVERCLOCKING


pi@raspberrypi: ~
File Edit Tabs Help
GNU nano 3.2 /boot/config.txt Modified
uncomment to force a HDMI mode rather than DVI. This can make audio work in
DMT (computer monitor) modes
#hdmi_drive=2
uncomment to increase signal to HDMI, if you have interference, blanking, or
no display
#config_hdmi_boost=4
uncomment for composite PAL
#sdtv_mode=2
#uncomment to overclock the arm. 700 MHz is the default.
over_voltage=6
arm_freq=2000
gpu_freq=750
# Uncomment some or all of these to enable the optional hardware interfaces
#dtparam=i2c_arm=on
#dtparam=i2s=on
^G Get Help ^O Write Out ^W Where is ^K Cut Text ^J Justify ^C Cur Pos
^X Exit ^R Read File ^\ Replace ^U Uncut Text ^T To Spell ^_ Go To Line

Two things up front: This may well void your warranty, and you're going to need active cooling. Little fans that attach to the Pi's GPIO pins are easily found online. Don't trust a heatsink, no matter how massive. Get a fan. The Pi 4 has a quad-core processor that jogs along at 1.5GHz but can go faster—we regularly run ours at 2GHz. And Windows is sluggish enough even with an overclock.

You need to edit the "config.txt" file in the root directory of the Boot volume. You can put it in your PC and edit it from there, or open Terminal and type `sudo nano /boot/config.txt` to open it in the Nano text editor. The config file is nicely laid out, making it clear what goes where. Add these lines under the line `#uncomment to overclock the arm`:

```
over_voltage=6
arm_freq=2000
gpu_freq=750
```

Save and quit Nano with Ctrl-o and Ctrl-x. That's as high as we like to go, but you can try 100MHz or so more if you're brave. If it ever fails to boot, restart using the power switch and hold Shift. You can add a temperature monitor to the taskbar that shows how hot your Pi is getting—it will throttle beyond 80 C. To monitor your CPU frequency, open Terminal and type `watch -n 1 vcgencmd measure_clock arm`. Open a few apps and watch it climb to 2GHz.

© RASPBERRY PI FOUNDATION

Machine of the Month: Sega SC-3000 (1983)

YOU'LL NEED THIS

BINARIES

Binaries for Windows x86 are available online (www.smspower.org/meka), along with binaries for older Linux and DOS versions. Linux users may want to run newer Windows binaries through Wine.

A MICROCOMPUTER? FROM SEGA? That may seem a strange idea, but before its famous consoles, Sega briefly experimented with home computing.

Until the 1980s, Sega's income came mostly from arcade machines, but the booming market in home gaming and home computing was simply too big to ignore, and it was time for Sega to test the market.

Sega was unsure whether to put its weight behind home computers or simple game consoles. The company decided to hedge its bets with both: a console, the SG-1000, and a microcomputer, the SC-3000. Each model is based on the same underlying hardware.

These machines provide an excellent way to explore Sega's earlier software before its worldwide console-gaming success. And the SC-3000 provides a glimpse of what Sega would have been like had it continued down the path of home computing.

However, the SC-3000 never had a North American release, and even in its best markets, machines are rare nowadays. Emulation is now the only real option for most people, so allow us to show you the easiest ways to emulate the SC-3000 on your own PC after we take you through a brief tour of its history. –JOHN KNIGHT

1 RELEASE

Launching in July 1983, the SC-3000 had a limited release worldwide, shipping to Japan, France, Italy, Finland, Spain, South Africa, Australia, and New Zealand. Its launch price of 29,800 Yen was substantially cheaper than the dominant Commodore 64, but with competitive levels of performance.

›› Hardware-wise, the SC-3000 is essentially just an SG-1000 console with a keyboard, and is entirely compatible with SG-1000 games. The CPU is an NEC D780C-1 (a clone of the Zilog Z80A) running at 3.58MHz, and its video coprocessor can display 32 single-color sprites on screen.

›› The SC-3000 was built using off-the-shelf parts and is close to the MSX standard—many MSX titles were Sega ports. However, SC-3000 and MSX software is not cross-compatible. The Sega has a superior sound chip, no built-in operating system, and only 2KB of system RAM. Most memory was actually supplied on software cartridges, and the machine doesn't function without a cartridge inserted.

›› Like the ZX Spectrum, initial models came with cheap rubber keyboards, and entire BASIC commands were assigned to single keys. The more expensive SC-3000H model soon followed with a proper keyboard.

2 SOFTWARE

Most software comes on ROM cartridges, the Sega My Card format, or on cassette; 3.5-inch floppy support was available via the SF-7000 expansion box, which also added 64KB of RAM, but these were very expensive, and disk-based software isn't common.

›› Beyond Sega's official titles, most other applications were tape-based releases from Australia and New Zealand.

›› Gaming-wise, the experience is similar to the MSX, with a slightly higher standard of presentation. The sound is also better, with a very distinctive crystal-like tone. Most games use a two-button joystick layout.

›› To pick some highlights, *Star Jacker* is an innovative vertical shooter; *Elevator Action* is a fan favorite; *Girl's Garden* is a weird gem from the creator of *Sonic the Hedgehog;* and *C-So!* has a crazy platforming mechanic.

3 LEGACY

Despite having a reputation as a commercial flop (Sega's sales figures were only in the thousands, and were dwarfed by Nintendo's Famicom), the SC-3000 and SG-1000 outsold Sega's projected sales figures significantly. Between the SC-3000 and the SG-1000, the SC-3000 microcomputer sold more units than its console sibling.

›› While the SC-3000 had moderate sales in all of its launch countries, most sales were either in Japan, or Australia and New Zealand, where it still has a cult following today.

›› However, Sega recognized the machine's weakness toward business applications and felt further machines wouldn't compete in an already saturated home computer market, so pulled out in 1985.

›› Although Sega mostly abandoned home computing after the SC-3000, the successful production run inspired Sega to keep producing game consoles, leading to 1985's Mark III console—or Sega Master System, outside Japan.

›› ***Exerion*** **(1983) features a cool faux-3D moving backdrop and provides a fresh take on *Galaga*-style gameplay.**

© EXERION

›› This black model was the most common worldwide, but white models were available in Japan, and red models in Spain.

FINDING SOFTWARE

The official Sega software collection isn't large, and full collections of Sega ROM cartridges are on Archive.org for both SG-1000 and SC-3000 software. For anyone willing to get stuck in and learn how to program the machine, issues of New Zealand's *Sega Computer Magazine* are also available at Archive.org.

Anyone wanting to keep an eye out for new SC-3000 developments should check out www.sc-3000.com. For the more hardcore users (and perhaps even actual SC-3000 owners), http://sc3000-multicart.com has new cartridge-based hardware available for the machine, as well as tape audio archives.

4 EMULATION

If you only want to play SG-1000 console games, the easiest option is to use Kega Fusion (www.carpeludum.com/kega-fusion), which supports Windows, Linux, and MacOS. The interface is intuitive and fairly self-explanatory, but to load SG-1000 games, just act as though you are loading a Master System game by clicking "File → Load MasterSystem ROM."

›› If you specifically want to emulate the SC-3000—especially if you want to use keyboard inputs and BASIC—we recommend MEKA (www.smspower.org/meka). MEKA also runs Taiwanese titles, while Kega Fusion does not. Officially, MEKA supports Windows and Linux, with older versions also running on DOS. However, the Linux version needs to be compiled from source.

›› The MEKA project is seeking a Linux maintainer to provide pre-made binaries (if you feel up to the task!), but for now, Linux users may want to use the Windows binary through Wine instead.

›› The website provides a ZIP file with Windows binaries. Download and extract the ZIP file, then open the new folder. The executable is called mekaw.exe, and may require you to allow Administrator privileges, depending on your installation. MEKA doesn't come with a self-installer, so you may want to make a desktop shortcut to the executable.

5 GETTING STARTED

On your first run, there is a setup window where you can choose your video driver, resolution, and language settings. Click "OK" and you're taken to MEKA's main screen. To load a normal game ROM, you can either use the Load ROM window, which is enabled by default, or from the top menu, click "Main → Load ROM." This opens a file browser. Select your ROM file and click "Load."

›› Your game should now load within the MEKA window. Press Alt-Enter to switch to full-screen mode. Press Escape to switch between the full game window or a small window within the MEKA home screen.

›› By default, MEKA has its controls set to emulate a Master System controller on the keyboard. Player 1's controls are set to the arrow keys for movement, Z and X for Button 1 and 2, Space for Pause/Start, and Backspace to reset the emulated machine.

6 LOADING BASIC

Getting BASIC to function is slightly more difficult, however, because you need to enable keyboard emulation. You also need to find a BASIC cartridge ROM, because the Sega didn't come with a built-in operating system.

›› To get started, enable keyboard emulation by either choosing "Inputs → Sega Keyboard" from the top menu, or by pressing Ctrl-F9. You'll see a Japanese keyboard appear at the bottom of the screen. Now load the BASIC cartridge like any other ROM, and MEKA should accept keyboard inputs.

›› In the likely event that you can't find the right key to press, you can press Escape to return to the home screen and examine the visual Japanese keyboard for keystroke references.

SPECIFICATIONS

SEGA SC-3000 (1983)

CPU:	NEC D780C-1 @ 3.58MHz
VRAM:	16KB
RAM:	2KB embedded, expandable up to 64KB by cartridges or add-ons
Launch price:	¥29,800
Graphics:	16 colors @ 256x192, 32 on-screen sprites via Texas Instruments TMS9929A coprocessor
Sound:	Texas Instruments SN-76489AN PCM
Storage:	ROM cartridge, Sega My Card, cassette, 3.5-inch floppy
OS:	None, Sega BASIC available on cartridge
Released:	July 1983
Production:	1983–1985
Worldwide sales:	Unknown

›› Master System classic *The Ninja* was the SC-3000's *Ninja Princess* (1986) originally, and is much loved by Sega fans.

© WIKIPEDIA, SEGA

BUILD IT

ZAK STOREY, EDITOR-IN-CHIEF

Upgrade, Upgrades, Upgrades

Z490 with an 11th-gen chip. Is it worth it?

LENGTH OF TIME: **1-2 HOURS** | LEVEL OF DIFFICULTY: **EASY**

THE CONCEPT

LET'S FACE IT, Intel's latest launch has been a little lackluster. At least at the top end. The Core i9-11900K is, technically, a fantastic piece of engineering (a compliment we keep having to throw Intel's way these days), because it circumvents a lot of the limitations of 14nm and the previous architecture design. However, when it comes to outright performance and pricing, Rocket Lake sort of falls flat on its face rather swiftly—at that aforementioned top end, anyway. That's not good. We really need Intel to break through that 10nm barrier, and deliver, en masse, newer chips for the health of the industry as a whole. Regardless of whether you're a fan of Team Red or Team Blue, having two competitive chip makers means that we, the consumers, will see significant improvements, generation to generation. And that's something that, apart from meaning faster, better-performing rigs for us, also extends to benefiting society. Heck, we don't want to see this all boil down to ARM versus AMD, RISC versus x86, in 10 years' time. That would be sad indeed.

So, was everything a dud in Intel's latest launch? Well, no. Bizarrely, and in perhaps the biggest turn-around in history, Intel's budget-oriented chips are actually far more interesting than those at the top of the stack, and even more so than AMD's. The Core i5-11400 and Core i5-11600K in particular are quite interesting, especially for those who only have one ambition for their rigs: gaming. In fact, in many cases, they entirely outpace their red rivals at the lower end of the spectrum. Long gone are the days of "If you're on a budget, go AMD." Yet there's a catch....

THE IMPOSSIBLE TASK

THERE'S JUST NO WAY of getting out there and buying modern components today. It's almost impossible outside of a select few areas. Storage, power supplies, cases, cooling, peripherals, some motherboards, and Intel CPUs are in steady supply, no doubt the latter due to the 14nm process being fairly under-utilized at this point by the majority of the industry. But trying to find a graphics card in this hellish mining boom ecosystem is nigh-on impossible.

We're very fortunate, with the fact that there are indeed some press samples in circulation that we can take advantage of here at M*aximum PC*. Not least the card we've chosen for this issue: AMD's latest Radeon RX 6700 XT. But even we've had to borrow this card specifically from our colleagues at PC Gamer for a week, purely to build, shoot, and test this system, because AMD had no spare samples available for us.

So, we're pitching this build around the concept of an upgrade, effectively. You've had the majority of these parts for a while now. You managed to pick up a Core i5-10600K way back when it launched in 2020 (yikes), along with a Gigabyte Z490 motherboard, complete with PCIe 4.0 compatibility, and thanks to being extremely lucky with some pre-orders, got hold of a 6700 XT and an i5-11600K, although the chip wasn't exactly too difficult to source.

The big question: Does the Z490 board do the job with the latest-gen chip? And if you were to build this rig from scratch, what would $2,741 get you in terms of gaming performance in this silicon drought-ridden world we live in? Let's find out.

INGREDIENTS

PART		STREET PRICE
Case	Lian Li PC-O11-Dynamic Full Tower	$150
Motherboard	Gigabyte Z490 Aorus Pro AX	$155
CPU	Intel Core i5-11600K	$263
GPU	AMD Radeon RX 6700 XT	$1,100
Memory	16GB (2x 8GB) Crucial Ballistix DDR4 @ 3,600	$94
PSU	850W Be Quiet! Dark Power 12 80+ Titanium	$240
Primary Storage	1TB Samsung 980 Pro M.2 PCIe 4.0 SSD	$200
Secondary Storage	2TB Western Digital SN750 M.2 PCIe 3.0 SSD	$310
CPU Cooler	360mm EKWB EK-AIO D-RGB	$155
Fans	3x Phanteks PH-F120SK	$42
OS	Windows 10 Home 64-bit OEM	$32
Total		$2,741

1 LEGENDARY LIAN LI

WHY WE'VE NEVER done a "Build It" using the legendary Lian Li PC-O11-Dynamic chassis before is beyond us. It seems to have slipped through the net at *Maximum PC*. We've used it across other brands, and we've known for years that it's exceptionally well built. In fact, it's perhaps the best case available right now for anyone looking to build in an ATX tower. And yet, somehow—amid all its accolades and awards—we've never thought once of documenting a build in it, outside of recommending it for "Blueprints," of course. Crazy.

The O11-Dynamic is an absolute beast. It is a full-tower, cube-shaped, dual-chamber case, with capacity for up to three 360mm radiators in the front alone, E-ATX motherboard support, dual power supply options, and vertical GPU support, along with enough accessories to make your eyes bleed, all packed together with a lovely flourish of smart brushed aluminum and tempered glass. And the cherry on top? You can also pick it up in silver.

2 INTUITIVE PANEL REMOVAL

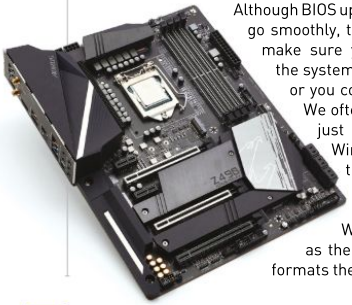
GETTING TO GRIPS with it, the first thing we did was strip our case down to its bare bones. The PC-O11 has quite an original design when it comes to removing the panels. First, you remove the top of the case; there are two thumbscrews at the back to loosen. Once that's off, the two glass panels, secured by a stealthy notch and latch mechanism, lift up and out. It's all super-clean and surprisingly secure for a chassis of this size.

There are no thumbscrews, magnetic hinges, or anything along those lines, giving it a super-tidy look overall. We've also gone ahead and removed a few interior panels here, namely the 3.5-inch hard drive cage above the PSU, as well as a cable tidy bar, just to give us as much room as possible to work in.

3 MOBO PREP

NEXT ON THE AGENDA is our motherboard, the Z490 Gigabyte Aorus Pro AX. If you do plan on using a Z490 board, you need to update the BIOS to the latest version. Note, most Asus boards don't support 11th-gen chips or PCIe 4.0 devices, so double-check before investing in a new CPU that your board can support it.

To update your BIOS, you need a USB stick, formatted to FAT32. Download the correct BIOS version from the mobo's support page (for the Gigabyte Z490 Aorus Pro AX, we need the F20d BIOS released on March 12), and extract it to the stick. Once the PC's built, pop in the stick, power on the rig, mash the Delete key, and look for the BIOS Flash tool in the BIOS. Select the file on the USB stick and wait while it does it's magic. Word of warning: Although BIOS updates almost always go smoothly, things can go wrong; make sure you don't power off the system during the upgrade, or you could brick the board. We often upgrade the BIOS just prior to installing Windows, placing the BIOS file on the same USB stick that we use for the Windows 10 installer, as the Media Creation tool formats the USB stick to FAT32.



4 PCIE 4.0 TESTING

OUR STORAGE for this build isn't technically what we would recommend for this kind of spec. Basically, it's massive overkill. A 1TB PCIe 4.0 drive for your operating system will be zippy as heck, but at $200, it's hardly cheap—same goes for the 2TB PCIe 3.0 drive we're running for backup storage. These two drives are purely here to see how they perform on a previous-gen motherboard, which is supposedly PCIe 4.0 compatible, with a BIOS upgrade, and Intel's first gen of PCIe 4.0-supporting processor.

That's not to say these aren't fantastic components. Indeed, the 980 Pro would be our PCIe 4.0 drive of choice (that, or the Sabrent Rocket 4 Plus) for anyone looking for a high-spec enthusiast-class primary drive.

7 ROOM FOR ACTIVITIES

TO INSTALL THE MOTHERBOARD, line up the holes in the board with the stand-offs in the case, and the integrated rear I/O shield with the cutout in the back of the chassis, and place it down. It's best to do this with the case on its side, so you're not fighting gravity. Then, carefully secure the motherboard into position. Make sure you use the correct screws, so you don't strip the stand-off threads. There's nothing worse than using the wrong screw, then having the stand-off spin as you try to free your trapped motherboard if something goes wrong.

Also, check out all the space. It's a seriously big case, and the angled cable grommet area allows larger E-ATX boards to fit in, albeit with a slight overhang.

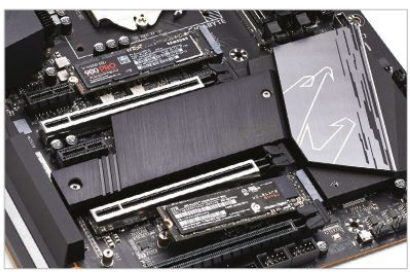
8 REAR I/O & HDDS

HERE YOU CAN SEE we've removed the hard drive cage from the back of the chassis, as our build technically doesn't require it. This has given us some extra cable management space, although, to be fair, given the design of this chassis, that's never going to be a problem.

Perhaps the oddest element of the PC-O11-Dynamic is the recessed rear I/O portion of the chassis. Don't get us wrong, it's a classy case, but it seems strange to recess the I/O so far back, especially as light is traditionally hard to come by when plugging cables into the back of the motherboard tray like this.

5 THE RIGHT SLOT

BECAUSE Z490 AND PCIE 4.0 are fickle friends, installing your storage correctly is vital. The PCIe 4.0-compatible slot on the Z490 Aorus Pro AX isn't documented on Gigabyte's website, but it's this top slot. The manual states that this slot is called M2B_CPU (note: reserved), and has no use. But the two other M.2 slots under the heatsink are labeled M2A_SB and M2M_SB, SB standing for southbridge, or the chipset. Intel's 10th-gen chips don't have the PCIe 4.0 lanes capable of driving that slot at the top (reserved for 11th-gen chips and PCIe 4.0), and the two southbridge slots go via the DMI in the Z490 chipset, which connects to the CPU, operating at PCIe 3.0 x4. Pop in an 11th-gen chip, update the BIOS, and the top slot operates in PCIe 4.0 x4 mode direct to the CPU. Neat.



6 MOUNTING IS A GO-GO

WITH ALL THAT STORAGE FUN out of the way, and the memory and processor installed with the motherboard outside of the case, it's time to start installing the backplate. EK's backplate system is far less complex than the Be Quiet! one we were fandangling with last issue, that's for sure. Line the backplate up on the rear of the motherboard, and secure the stand-offs in position through the four mounting holes. Turn these by hand, so you don't overtighten them, and you'll be good to go.

Once that's all wrapped up, it's time to get the motherboard into our shiny, empty Lian Li chassis.

9 NO, SERIOUSLY

IT'S A CRAZY AMOUNT OF ROOM. In fact, you can install twin power supplies in the back if you want. Lian Li includes a fairly substantial rubber block you can use here, which sits between the two PSUs, stacked sideways on top of each other. If you did want to go that route with a single system, you'd have to find some way of bridging them, so they both initialize at the same time. Phanteks used to sell a power combo that could do that for you, but it seems to no longer be available. This element is a little odd, if we're honest, as there's not really space for a secondary ITX system, where it would make a lot more sense.

10 ALL OF THE POWER

OUR POWER SUPPLY OF CHOICE for this rig is the Be Quiet! Dark Power 12 850W. It's a beast, and Be quiet!'s really nailed down its aesthetic to a T: silver-embossed logos, super-slick industrial-style grilles, and, of course, an epic fan at its heart. This 850W PSU is more than enough for what we're building here today; in fact, it's over twice what we think this system will draw from the wall. It also comes with some flashy, overly large thumbscrews.

It's slightly less flashy than the Dark Power Pro 12 series, and doesn't come with pre-sleeved cables, but practically everything else is the same, even the efficiency rating. So, if you're just looking for a top-notch power supply without the fluff, it's a good pick.

11 CABLING BEFORE ALL

YEAH, WE DECIDED to go this route this time around and install the cables first—basically, because we weren't quite sure how to install the AIO. Traditionally, they're something you install in the roof; that said, in our 5000D, we managed to install it in the side of the chassis, and that looked pretty stellar.

To that end, we decided to run all the cables first. There's nothing too out of the ordinary here, although one thing we will point out is that the USB 3.0 and USB C headers look rather ugly, due to the position of the connectors on the board, and that angled cable management grommet system we were praising earlier.

12 SPLODGE? SPLODGE!

WITH ALL THE CABLES we needed installed (opting for a single eight-pin EPS power for this setup), we installed EK's 360mm AIO block on the board. This was a cakewalk, and once again goes to show just how nice this thing looks on a board with enough space (here's looking at you, Z490-I ROG Strix Gaming).

Simply attach the Intel bracket to the waterblock, remove the protective film underneath, add a splodge of your favorite thermal paste, position the block over the stand-offs, place the tiny springs over the stand-offs, and secure down in a star pattern, using the included screws. You can use a screwdriver to finish off the job—just make sure you don't use an electric one, or you may overtighten the cooler and crack the CPU's PCB.

13 FAN-TASTIC OPTICAL ILLUSIONS

WE DECIDED TO RUN THE AIO out through the roof, and set up the three EKWB fans as exhausts. The only downside to the Lian Li PC-O11-Dynamic is the lack of fans. You're expected to provide your own. We've gone with three 120mm Phanteks RGB fans acting as an exhaust; with their typhoon-style blades and side-mounted location, the image below can play tricks on your eyes.

If you struggle with daisy-chained RGB connectors, we recommend using parcel tape, gaffer tape, or electrical tape to stick the RGB connectors together loosely around the back, so they don't come undone. Works a treat!

14 THE RARE SPOTTED RX 6700 XT

THESE THINGS SHOULD be designated an endangered species at this point. Our final step in the whole build process was installing our shiny new AMD Radeon RX 6700 XT. We removed the two PCIe covers from the back of the case, lined it up with the uppermost PCIe slot, and slotted it into position, before resecuring it back down, and installing the PCIe power cables that we'd left out specifically for it earlier.

This is one of the "Made by AMD" models, and as such it's, well, got bright red accents on it. Somewhat annoying. AMD did release a Midnight Black version earlier this month, but perhaps unsurprisingly, they were sold out within seconds, and immediately relisted on eBay for three times the RRP. Yay.

1 **At the moment, we're running a heavily negative pressure system; installing three intake fans in the floor would help remedy that.**

2 **A nicer-looking graphics card without the red accents would help, too, but let's be fair, we should be happy we have a card at all.**

3 **If you were running this rig for personal use, day in day out, we'd swap the three side fans here, so they were intakes instead.**

4 **The 980 Pro SSD below the CPU may not have a heatsink, but its natural copper-laced sticker should help keep it cool.**

RETRO BOARDS

THERE YOU HAVE IT: one crisp clean Lian Li upgrade build, complete with PCIe 4.0 drive, Intel Core i5-11600K, and AMD Radeon RX 6700 XT. We're super-happy with how it turned out, even if it is running in a negative pressure configuration. It looks excellent, and that RGB fan setup is kick-ass. Ideally, it does need a few extra fans; three intakes in the bottom blowing cool air up into that GPU would add an extra splash of light and help with temperatures. The PC-O11-Dynamic is what we call a chimney or funnel design—unlike most cases that draw cool air in through the front and exhaust it up and out, a chimney design is assisted by natural convection, as it pulls cool air in through the bottom and then pushes it up and out through the roof. That's why the O11 has a magnetic dust filter below those bottom three intakes.

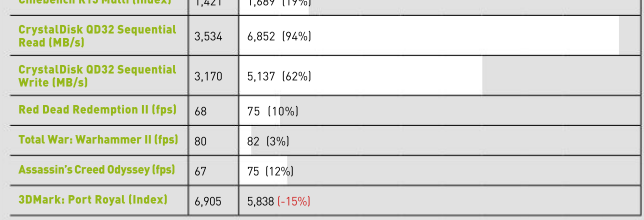
The build itself went super-smoothly. The one thing we would say is that installing the radiator in the roof was a little tricky, as it doesn't have a removable radiator bracket, but having one there would add to the bulk, and may have led to an uglier finish aesthetically. And let's face it, you install a radiator once, it takes five minutes of messing around, then it's in place for the next six months to several years anyway.

As for performance, the Core i5-11600K is a fine piece of gear. In multicore performance compared to last-gen's 10600K, we're seeing figures 20 percent higher across rendering tasks, which is impressive, and it also does better in gaming, no doubt thanks to higher single-core IPC. It's not quite as big a difference compared to AMD's Ryzen 5 5600X as we'd like, but all things considered, it's not bad, and it is cheaper and in stock. We were worried about PCIe 4.0 performance, given the fact that it's an older series motherboard, but performance with the 980 Pro landed right where we expected it, with reads in the high 6,000s and writes in the low 5,000s.

We decided to compare this rig against a similarly priced machine from last year, our Razer Tomahawk ITX build, which housed the RTX 2080 Super from Zotac. Impressively, the RX 6700 XT could easily keep pace with it in 1440p gaming. In fact, in almost every benchmark, it outperformed the old juggernaut by a comfortable 10 percent or so, with the only exceptions being *Total War: Warhammer II* and ray tracing, as the 6000 series doesn't quite have the same dedicated hardware that Nvidia is using to deal with ray-traced shadows and resources.

Question is, should you build this system today? Well, if you have most of the parts already, and feel the need for an upgrade, it's not a bad move. At 1440p, it's a solid build, but you do need to find a GPU, and you are going to be paying $600 for the privilege. If you can, snap up a new GPU at retail price or get on a pre-order list. But we recommend you look at eking out extra performance where you can without breaking the bank, namely with your case setup, cooling, and peripherals. In a year or two, hopefully the silicon shortage will end, and you won't be out of pocket sitting on a rapidly depreciating graphics card.

BENCHMARKS



Our zero-point consists of an Intel Core i5-10600K, an Asus Rog Strix Z490-I Gaming motherboard, Zotac GeForce RTX 2080 Super AMP Extreme GPU, 16GB of Corsair Dominator Platinum RGB @ 3,600, and a 2TB Samsung 970 Evo Plus M.2 PCIe 3.0 SSD. All games tested at 1440p on the highest graphical profile.

LAB NOTES

ZAK STOREY, EDITOR-IN-CHIEF

Canadian Bob Ross & Age of Empires II

Unwinding after a hard day's work (dealing with subscriptions)

I AM EXHAUSTED. Broken. The subscription situation is soul-destroying. It now takes up a huge chunk of my working week, and I'm massively behind on responding to complaints. I apologize. I'm trying to get on top of it as fast as I can. *Maximum PC* seems to be one of the worst affected magazines, and I'll continue to raise any tickets that come through with our priority team. So, if you do have problems that aren't being resolved via the usual channels, please get in touch via editor@maximumpc.com.

Because of that, and a few other things going on, I haven't been sleeping much (I imagine this is the case for a fair few folk right now). To shut off and chill out in the evenings, I've taken to watching one particular YouTube content creator, known as Spirit of the Law (bit.ly/MPCSotL). He's a Canadian *Age of Empires II* player, who looks at the math behind the game, and how it all works. I've been watching his content for over a year, and watch it just before I go to sleep. I find it amazingly soothing, yet informative too. I'm not affiliated with him, never even spoken to the dude, but, it's almost become a night-time ritual of mine to crash out watching one of his videos on Lanchester's Law, or how building armor works, or whether trade carts are better than trade cogs for generating gold—you name it.

Age of Empires II is a classic given new life through its HD and Definitive Edition remasters.

The thing is, I don't even play *Age of Empires II*. Not properly. Just the odd game every so often. It's still a fantastic RTS. In fact, the Definitive Edition is an exceptional remaster. It's even getting new expansions. And it's a game I cherish, because it was one of the first titles I played on PC. Anyway, the dude is like a Canadian Bob Ross for me. His content is just so chill, and it always knocks me out. It also helps that his journalistic testing quality is top-notch.

SAM LEWIS

Staff Writer

I drive a VW Golf Mk6, which is perfectly adequate for me. It's light, nimble, powerful enough, and good on fuel. But it's let down by its outdated infotainment system, with a red pixel display, and no GPS.

I wanted an alternative to a built-in Apple CarPlay head unit, which won't alter the car for when I sell it. That's when I saw on YouTube that you can use an Android tablet with a wireless CarPlay USB adapter instead.

I picked up an Amazon Fire HD 8 for $120, a USB C hub, a USB A car link dongle, and a car tablet mount. This way, I can experience Apple CarPlay for around $200, be free to use the tablet for anything else, plus add it to any future car. Result.

DAVE ALCOCK

Contributor

I just don't understand coiled keyboard cables with Aviation or LEMO connectors. These allow the cable to be split halfway down. I did think it was for those who need to swap cables often, and would be perfect when reviewing, for quickly swapping between products and keyboards. But they're mostly only sold as a single unit and don't have multiple ends to swap out, making the connector pointless. Apparently, they're just for looks, which I get, kind of, but the fact they're such a big craze in the keyboard world irks me. Pretty cables are fine, and I know spending vast amounts on custom keyboards is obscene, but $50 for a connector that's never used? Please, no.

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Editor's Pick:
Samsung Galaxy S21 Ultra

The ultimate smartphone?

I'VE DONE IT. Finally, after making my way through another chunky 24-month contract, I've gone and invested in a new smartphone for myself—none other than the Samsung Galaxy S21 Ultra.

I've had a bit of storied history with phones. I was there for the Nokia 3310 (albeit eight years old), and since then have jumped around a fair bit. My early years were filled with Nokias (N95, anyone?), Samsungs, and Sony Ericssons, but my first "proper" smartphone was the iPhone 4 back in 2011, which is when I really got hooked. Although the iPhone 4 was an impressive bit of tech, iOS just couldn't hold my tinkerer's mind, so I ditched Apple and didn't look back. Since then, I've had fun with the HTC One M7, Samsung Galaxy S7 Edge, the Galaxy S9+, and most recently the Huawei P30 Pro. That last pick was interesting. At the time, I was working for Tom's Hardware, and needed the best camera phone I could get. A lot of the review photography was done via smartphones or a decent DSLR, and as I didn't have the cash for the latter, a top-end smartphone was the way to go.

I knew the Huawei P30 Pro was going to be the last device Huawei produced with continued Android support, and its cameras were pretty epic—at least, compared to the S9+—so I took the risk, and picked one up. All in all, it was a darn good phone, but the contract rolled around and it was time for a new one, so after some extensive research, being torn between going back to Apple with the iPhone 12 Pro Max, or the OnePlus 9 Pro, I ended up with the S21 Ultra.

First thing I gotta say is it is expensive, but oh my days, it's nice. The camera elements, in particular, are ludicrous. There are four separate lenses on the back, and a laser autofocus element, with optical zoom all the way up to 30x, plus a massive 108MP main sensor. Even the front-facing camera packs in a 40MP sensor on its own. That's the same as my Huawei P30 Pro had on its main camera.

Then there's the display: 120Hz at 1440x3200 resolution for a 515 ppi density—buttery smooth, of course—and a max brightness of 1,500 nits. The feel of it in the hand, the materials used, the battery (5,000mAH), 12GB RAM, 128GB of storage, with a 5nm eight-core processor, and one of the big selling points for me, support for Wi-Fi 6E—it's all there. As a PC enthusiast, you can't help but look at this thing and just be in awe. It's incredible.

I mean, I get that it's new, and it's mine, and it's always nice to have an upgrade, but there's not a moment when I don't pick this up and enjoy my time with it. Photography, in particular, is exceptional, and I take a lot of photos, whether that's of products, or just out and about, me and the pup in the forests where I live—I couldn't be happier.

It's not perfect; the cost is definitely a big factor—it comes in at $1,020. It's bulky, too, and all those features do affect its battery life somewhat (thus the need for the 5K beastie), and then there's the worry of damaging it. I've accidentally dropped it once already, just after I'd come back from a 30-minute jog, so I immediately purchased a case for it.

Part of me questioned whether it was worth upgrading at all. I am paying close to $75 a month for it. I could have easily just got a basic plan and kept using my Huawei P30 Pro for the next year or two. But if I'm honest, I'm a little worried about the future, especially with the chip/silicon shortage, so this almost seemed like a sensible decision. Sort of. **–ZS**

$1,020, www.samsung.com

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87 Creative SXFI Gamer headset

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Courtesy of our friends over at *PC Gamer*, read the full review here: https://bit.ly/PCGInteli5

Intel Core i5-11600K

Where Rocket Lake shines

WE RECKON the Intel Core i5-11600K is Pat Gelsinger's favorite CPU in this new 11th Gen Rocket Lake lineup, it's certainly ours so far. Intel's new CEO has been speaking at length recently about his desire for the company to return to its heyday—a return to the tick-tock CPU production cadence of yesteryear, and to putting engineering at the forefront of everything the company does.

And the i5-11600K has a little of the nostalgia chip about it to us; a return to the days when our recommendation around a new CPU architecture would inevitably fall to the Core i5 CPUs rather than the top-end i7s. In this case, it's a really strong recommendation over the lackluster Intel Core i9-11900K.

This is one of the only new processors that should interest PC gamers from Intel's 11th Gen desktop CPUs, and is probably the go-to chip for anyone looking to build a mainstream gaming PC today. Y'know, if you can find a graphics card to go with it....

It's Intel's top-end six-core CPU from the Rocket Lake range, offering solid clock speeds, HyperThreading, unlocked multipliers for making with the overclocking, and a $270 price tag that makes the $350 Ryzen 5 5600X look positively pricey.

It's a different proposition within the 11th Gen lineup compared to the 11900K, too. Where the i9 is weaker, on paper, against its last-gen equivalent, with fewer cores and lower overall clock speed, the i5-11600K improves on its 10th Gen forebear almost across the board.

The only point it doesn't is in the almost irrelevant base clock figure of 3.9GHz. The Core i5-10600K has a nominally higher 4.1GHz base, but you never really see that in use anyway. But the all-core figure of 4.6GHz (which you do see solidly in multithreaded workloads) and the 4.9GHz single-core number are both one step higher than the Comet Lake i5.

It's also got that PCIe 4.0 support baked into the CPU itself, though sadly not throughout the new Z590 chipset. We've not had the greatest experience with PCIe 4.0 performance from the Rocket Lake chips so far, neither from the top-end Core i9 or this i5-11600K. The ups and downs in our performance testing with the 11th Gen CPUs, however, do make us think this could be down to teething problems surrounding Intel's inaugural PCIe 4.0 platform.

In gaming, the i5-11600K is generally capable of offering practically identical performance to the 5600X, give or take a few frames per second here and there. It's also almost up there in comparison to Intel's i9-11900K, too. Suffice to say, this is a more than capable gaming processor that won't stand in the way of your graphics card's ability to render its silicon butt off.

But where that was all the Rocket Lake i9 could offer, the i5-11600K goes toe-to-toe with the 5600X in the rest of our benchmarks. The only place where there is a significant delta between the Core i5-11600K and the Ryzen 5 5600X is when it comes to power. The 7nm Zen 3 architecture is seriously efficient, ably demonstrated by the chip's peak wattage of just 76W. The Rocket Lake i5 hits 130W, and actually considerably more if you push it in multithreaded workloads.

This, and the cheaper Core i5-11600KF (sans iGPU), would be our recommendations for chips to buy in the new lineup. But it's this i5-11600K that gives AMD's 5600X a run for its money.

We're penny-pinching people when it comes to our builds, and the price/performance value of the Rocket Lake chip gives it the edge for us. Sure, it's more power-hungry than the Ryzen chip, but let's be honest, that doesn't really bother you, does it? **–DAVE JAMES**

VERDICT **9** KICK ASS!

Intel Core i5-11600K

➕ **FLYING HIGH** Undercuts 5600X on price; excellent gaming performance; solid multithreading chops.

➖ **NOT QUITE RYZEN** Weak PCIe 4.0 support; power-hungry.

$262, www.intel.com

BENCHMARKS

	Intel Core i5-11600K	AMD Ryzen 5 5600X
Cinebench R20 Single (Index)	589	**600**
Cinebench R20 Multi (Index)	4,213	**4,292**
Tech ARP's x264 (Avg. fps)	35.37	**39.42**
Metro Exodus @ 1080p (Avg. fps)	**105**	**105**
Total War: Three Kingdoms @ 1440p (Avg. fps)	**159**	153
Far Cry New Dawn @ 4K (Avg. fps)	**83**	**83**
Price Per Thread	**$22**	$25
Recommended Retail Price	**$262**	$300

Best scores are in bold. Intel test bed consists of an Asus ROG Maximus XIII Hero, 32GB of Corsair Vengeance RGB Pro @ 3200, and an Nvidia GeForce RTX 2080 Ti. All games were tested on their highest graphical profile, with average fps noted. AMD motherboard is the Gigabyte X570 Aorus Master.

SPECIFICATIONS

Cores/Threads	6/12
Base/Turbo Clock	3.9/4.6GHz
Architecture	Rocket Lake
Lithography	14nm
Memory Support	DDR4-3200
PCIe Support	x16x4 PCIe 4.0
Integrated Graphics	Intel UHD Graphics 750
TDP	95W

Spectacular for productivity, with epic screen, incredible battery life, and great performance.

LG Gram 17

The ultimate lightweight powerhouse

THE LG GRAM 17 (2021) is the latest variant of the company's so-far superb lineup of productivity-oriented laptops that focus on being as light as possible above all else. Powered by Intel's 11th-generation mobile chips, it's a laptop that mostly allows for fast, hassle-free productivity, making your daily workload a seamless experience at the office or at school.

While the LG Gram 17 (2021) isn't going to win any awards for style, it does offer pure function, poising it as one of the best choices for everyday workplace use. If you can stomach the price.

Last year's Gram 17 cost just over $1,749 for a similar spec. That ran on a 10th-gen Intel CPU, so we've seen a bit of a price hike going to the Intel Core i7-1165G7 CPU. Other LG Gram 17 (2021) configurations are also available. There's a 512GB SSD config that costs a little less, at $1,749, and a 256GB version, which costs even less, at $1,699. Honestly, though, if you're already spending that much, plumping up the extra cash for the 1TB version seems like a solid deal.

Your immediate reaction when you first pick up the LG Gram 17 will almost definitely be how light it is. Weighing in at 2.98 pounds, the Gram 17 is fascinatingly lightweight, especially impressive given the extra bulk that the 17-inch screen provides. You might think that such a lightweight design comes at the cost of durability. After all, heftier laptops can give users peace of mind when it comes to preventing accidental damages. The LG Gram 17, however, is still impressively sturdy, featuring a full aluminum body that's resistant to drops, dust, and other common forms of wear and tear.

The laptop's feathery weight pairs perfectly with its general swiftness, too. Backed up by Intel 11th-generation processing power and a speedy PCIe 3.0 NVMe SSD, it boots up impressively fast. Another area where it absolutely excels is in its superb battery life. This is nothing new for the LG Gram series, but this latest model goes above and beyond even its predecessors in that regard, lasting just shy of 14 hours.

So, it's impressed us from a design perspective, but it's no slouch under the hood, either. Intel's 11th-gen quad-core eight-thread CPU does a great job at multitasking, enabling you to juggle multiple projects on the go, especially with that ridiculously fast RAM. It's also whisper-quiet, at least with our time working with the laptop on a day-to-day basis, with only slight humming and heat buildup registering during our benchmark tests.

Its physical look isn't going to wow everyone when opened up. In fact, it's rather inconspicuous. The laptop's aesthetic design is so plain that you probably wouldn't give it a second glance, unless you get to see its gorgeous screen in action. At a resolution of 2560x1600, the WQXGA LCD screen is big for a reason, and from a productivity standpoint, it's hard to beat. The heightened clarity offered by that resolution means you have more real estate to play with, and thanks to its IPS tech, color really pops, too.

As a laptop made for work and school use, it certainly gets the fundamentals right. One drawback, however, is that the LCD screen is prone to some screen glare, which can prove to be distracting in brightly lit office environments.

So, the question is, should you buy the LG Gram 17 (2021)? Well, if you're sick of laptops with poor battery life, and you commute a lot and need a high-performing device for general everyday work, with a quality screen on top, it might be perfect. But if its size is an issue, you may be better off with the LG Gram 15, or one of the smaller variants of this super-lightweight design. **–RHYS WOOD**

VERDICT **9** KICK ASS!

LG Gram 17

+ FEATHERLIGHT Excellent battery life; high-quality display; super-light, whisper-quiet.

– BENDGATE A bit of screen glare; touchpad could be better.

$1,796, www.lg.com

BENCHMARKS

	ZERO-POINT	
GeekBench 5 Single-Core (Index)	1,558	1,418 (-9%)
GeekBench 5 Multi-Core (Index)	5,397	4,532 (-16%)
3DMark: Fire Strike (Index)	5,083	3,707 (-27%)
3DMark: Time Spy (Index)	1,771	1,118 (-37%)
PCMark 10: Home Test (Index)	4,871	4,686 (-4%)
PCMark 10: Battery Life (Time)	11:42	13:48 (18%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point is the Razer Book 13 (2020), with an Intel Core i7-1165G7, Intel XE Graphics, and 16GB of LPDDR4.

SPECIFICATIONS

CPU	2.8GHz Intel Core i7-1165G7 (four-core, eight-thread)
Graphics	Intel Iris Xe Graphics
RAM	16GB LPDDR4X @ 4,266MHz
Screen	2560x1600 IPS panel
Storage	1TB M.2 PCIe 3.0 SSD
Ports	2x Thunderbolt 4 USB-C, 1x HDMI, 2x USB 3.2-A, 1x microSD slot, 1x audio jack
Connectivity	Intel Wireless-AX201 Dual-Band (Wi-Fi 6), Bluetooth 5.1
Weight	2.98lb
Size	14.97 x 10.24 x 0.7 inches

AMD Radeon RX 6700 XT

Big Navi slims down and speeds up

SO FAR, AMD's Big Navi (aka RDNA2) line-up has focused on the heavyweight end of the spectrum, but that all changes with the Navi 22 GPU and the RX 6700 XT. Take a brawny GPU with 80 compute units, and tell it to go work out and get down to half that size, and you end up with a smaller chip that happens to clock exceptionally well.

Building a fast graphics card involves striking a balance between many competing goals. Larger chips perform better, but they also cost a lot more and use more power. Crank up the clock speeds on a beefy chip and you'll end up with extreme temperature requirements. AMD has learned a lot over the past several generations, and while Navi 22 might not be the sleekest kid on the track, it has some seriously tuned engine performance.

And by that, we mean it clocks like a bat out of hell. We've grown accustomed to maximum GPU clocks in the 1.9GHz range. AMD's Navi 21 GPUs blast past that with Game Clocks of up to 2.25GHz. Navi 22 revs the engine even higher, and we routinely saw clock speeds of over 2.5GHz while gaming. Clock speed isn't everything, but all else being equal, higher clocks mean faster performance.

Take the previous generation RX 5700 XT, which has the same number of CUs as the 6700 XT. It had a maximum boost clock of 1,905MHz, while the 6700 XT cranks the dial all the way up to 2,581MHz—and we managed to break 2.8GHz with overclocking. Plus, it still includes a 96MB Infinity Cache to keep that data flowing, which helps alleviate some congestion that might otherwise come from the 192-bit memory bus. The net result is a 30 percent gen-on-gen improvement in gaming performance.

Besides screamingly fast clock speeds, the RX 6700 XT packs 12GB of GDDR6 memory and supports the full DirectX 12 Ultimate feature set: ray tracing, mesh shaders, variable rate shading, and more. It also supports VulkanRT. Unfortunately, in the games we've tested so far, Nvidia still holds an advantage in ray-tracing performance, but AMD tends to take the lead in non-RT games.

The RX 6700 XT does sport a few bruises and scratches on its otherwise impressive physique. While the chip is quite a bit smaller than Navi 21, the high clocks mean power requirements nearly match those of the RX 6800. AMD also still lacks a shipping alternative to Nvidia's DLSS technology, though FidelityFX Super Resolution should come out soon—but we'll have to see how it actually looks. Turn on all the RT effects in a game such as *Cyberpunk 2077* and it quickly becomes apparent that DLSS isn't just a nice extra; it's basically required on more modest GPUs.

The biggest problem with the RX 6700 XT isn't performance, though. It's finding the card in stock at anything close to official prices. The GPU shortages of 2020 haven't stopped, and all indications are that they'll continue perhaps well into 2022. Nominally priced at $479, $20 cheaper than Nvidia's RTX 3070 and $80 more than the RTX 3060 Ti, street prices right now are enough to make us weep. The RX 6700 XT currently sells for $900–$1,000 on eBay, about $400 less than the RTX 3060 Ti, but no one should pay that much money for cards that are supposed to cost less than half that much.

If you're lucky enough to find an RX 6700 XT for anything near $500, there's lots to like. It can handle just about any game at 1080p or 1440p and ultra settings. It should also match or exceed the latest consoles in gaming performance. But considering those consoles include storage, a potent CPU, and other extras for the price, it's a painful time to be a PC gamer right now. **–JARRED WALTON**

VERDICT **8**

AMD Radeon RX 6700 XT

+ LEAN 12GB; 96MB cache; good 1080p/1440p performance.

– LANKY Weaker RT performance; no DLSS; not very efficient; sold out.

$479, www.amd.com

BENCHMARKS

	AMD Radeon RX 6700 XT	Nvidia GeForce RTX 3060 Ti FE	AMD Radeon RX 5700 XT
Eight-Game Average (1440p/4K)	**90/52**	81/49	68/40
Assassin's Creed Valhalla (1440p/4K)	**80/43**	61/39	61/34
Borderlands 3 (1440p/4K)	**93/49**	74/42	66/36
Dirt 5 (1440p/4K)	**95/61**	86/56	72/44
Forza Horizon 4 (1440p/4K)	**185/119**	157/108	136/87
Metro Exodus (1440p/4K)	**72**/43	69/**44**	55/42
Red Dead Redemption II (1440p/4K)	**77/49**	72/**49**	54/36

Best scores are in bold. All testing conducted with a Core i9-9900K, MSI MEG Z390 ACE, 2x 16GB DDR4-3200 CL16, 2TB XPG 8200 Pro M.2 SSD, Seasonic Focus G 850W. Scores are average frame rates at 1440p and 4K ultra.

SPECIFICATIONS

GPU/Architecture	Navi 22
Lithography	TSMC N7
Game Clock	2,424MHz
Memory	12GB GDDR6
GPU Cores	2,560
TFLOPS FP32	12.4
TDP	230W
Display Connectors	HDMI 2.1, DisplayPort 1.4

Catch it if you can—the Radeon RX 6700 XT is not only super-fast, it's also difficult to find.

MSI MPG Artymis 343CQR

Miles ahead of the curve...

WHATEVER YOU decide to do, go ahead and absolutely own it. This, surely, is the philosophy behind MSI's MPG Artymis 343CQR. This thing is hilariously curved. Specifically, it's a 1000R panel. In other words, its arc is such that, if extended full circle, the radius would be just one meter (3.28 feet). That's some serious bend.

Whether such an extreme curve is actually a good idea is a subjective call. Some people love curved screens. Others, not so much. Which is probably why the proportion of curved monitors on the market has subsided. Certainly, curved HDTVs were a passing fad.

Anyway, one thing we're sure of is that curved panels make more sense on larger, wider aspect screens. Which is where the 34-inch MPG Artymis 343CQR enters the scene, with its 3440x1440 resolution 21:9 aspect ratio.

Curves aside, the 343CQR's headline speeds and feeds include 165Hz refresh and 1ms pixel response. The 1ms claim is courtesy of the more forgiving MPRT metric, rather than gray-to-gray. As for adaptive refresh support, there's AMD FreeSync Premium Pro certification, but officially no Nvidia G-Sync support, though it is possible to get G-Sync working with Nvidia graphics boards.

You also get VESA DisplayHDR 400 certification. Like all such monitors, that means there's no local dimming, so it can't deliver a true HDR experience. Unusually for an HDR 400 panel, however, the 343CQR clocks in at fully 550cd/m² for peak brightness. That's pretty punchy.

Were this an IPS panel, the worry would be backlight bleed and distracting IPS glow. But MSI has gone for a VA panel. On paper, that should help contain black levels, thanks to VA's superior contrast, and improve the HDR experience without the need for local dimming.

In practice, it does all that and more. This monitor zings. In fact, it delivers the best HDR performance we've seen in an HDR 400 panel. It's so vibrant and punchy.

A great showcase of just what this screen can deliver is *Cyberpunk 2077*, with its luscious, high-fidelity, ray-traced visuals. The 343CQR serves up one of the most immersive experiences we've seen in what is likewise one of the best looking games ever, bugs aside.

What's more, there's something about the extreme curvature and wrap-around feel that draws you into the game so comprehensively, the feeling you might need anything bigger than 34 inches becomes redundant. The 3440x1440 native res is also a great compromise between maintaining high frame rates and delivering plenty of graphical detail.

But what about response and latency? Pixel response has been the downfall of many a VA monitor. But not this one. First impressions aren't great, but that's because this screen needs around 10 minutes to warm up. Then it looks sufficiently fast and blur-free to justify the 1ms rating. Strictly speaking, the best nano IPS and TN panels are faster, but the 343CQR is no slouch. The same goes for latency. The 165Hz refresh rate is plenty for all but the most committed esports addicts. For anyone else, the 343CQR is buttery smooth and lightning quick.

As for downsides, one slight issue is that you can't just have a refresh rate counter up on the screen on its own. You have to have a bunch of other data, too. The extreme curve plus the relatively limited 1,440-pixel vertical resolution also compromises this monitor as a work tool somewhat. But that much is obvious from the spec sheet. What you learn when you actually experience this monitor is that, as an all-arounder, it's awfully, awfully hard to beat. **–JEREMY LAIRD**

VERDICT
9
KICK ASS!

MSI MPG Artymis 343CQR

+ AHEAD OF THE CURVE Seriously punchy panel; extreme curve makes for serious immersion.

– AROUND THE BEND Not exactly optimized for productivity; pricey.

$899, www.msi.com

SPECIFICATIONS

Panel Size	34-inch
Panel Type	VA
Aspect Ratio	21:9
Resolution	3440x1440
Response Time	1ms (MPRT)
Contrast	3,000:1
Refresh Rate	165Hz
Brightness	550cd/m²
Extras	AMD FreeSync, DisplayHDR 400

MSI's new gaming panel is ultrawide and uber curved.

Lian Li PC-011-Dynamic

Bulky brilliance

WE'VE COVETED AND recommended this case for some time, but it has a bit of a reputation among system builders as being, well, something of a cliche. Why? Mostly because it's almost too good. In fact, it's so good, and has received so many awards over the last couple of years, and been praised so much around the tech community for its incredible versatility, top-quality materials, and easy building experience, that it's almost become a meme. "Oh, there's another liquid-cooled Lian Li PC-011-Dynamic build log, complete with the usual tubing runs, and distribution plate setup."

That's not necessarily a bad thing, but when you're on the hunt for engaging builds and a sense of exclusivity and achievement, building in a chassis that everyone else has done to death can be off-putting. That's not to say, however, that it isn't a fantastic case. And, let's face it, we are getting side-tracked here, and being perhaps too nitpicky.

Indeed, it's the go-to chassis for liquid-coolers, for sure, and there's good reason for that. Cooling support for the PC-011 is exemplary. As standard, it can support up to three 360mm radiators in the front of the chassis alone, and we're not talking skinny boys here, but big chunky rads up to a maximum of 90mm. Then there's the numerous distribution plates available from third parties, pump mounting support, and maximum compatibility for up to nine 120mm fans in a more ordinary configuration, or 18 120mm fans if you run push-pull on everything with that triple-rad setup we mentioned earlier. It's nuts. In fact, our build on page 66 only houses six fans. We tried to find an additional three intakes for the bottom, but sadly ran out of RGB fans to achieve the illuminating feat.

And it's not just for liquid-coolers. From advanced air-cooling solutions to liquid-cooled behemoths to RGB giants, dual-PSU systems, and beyond, if you can think of it, someone's probably already got a detailed build log of it somewhere online, and another company's using it to advertise their own products elsewhere, too. It's such a popular case.

Its strengths are numerous. The design looks incredible, the tempered glass really adds a fantastic accenting glamor to the whole thing, and the interior setup and layout are easy to move around in and extremely versatile, enabling you to install all manner of hardware in any way you can imagine. You can install a 360mm AIO in three separate locations, you could have vertical GPUs if you want, you can do all that with enough fans to float a hovercraft, and then there's the rear of the case, littered with even more options. It can support dual power supplies. It has a dedicated 3.5-inch hard drive caddy. There's vast amounts of room for cable management, plus smart cable grommeting all around, too. It's crazy how much is included. It's perhaps the best dual-chamber chassis we've ever seen. And the fact it's available at $160 makes it one of the best value cases you can get at this price point, too. Its only weaknesses lie in its size and perhaps its lack of expandable storage options. This thing is a hefty old case, measuring 10.7 x 17.6 x 17.5 inches, and as it only supports six drives in total (four 2.5-inch drives and two 3.5-inch drives), for a case of this caliber, we'd like to have seen a way of mounting additional 3.5-inch hard drives, perhaps on that side-mounted radiator location, as an optional extra.

There's a good reason why this case has turned into such a meme, and even though system-builders and enthusiasts like ourselves like to rib on it for being such a common case, rather like Ford's F-Series pickup trucks or the Volkswagen Beetle, this thing does its job well—really well. And you can't hate it for that. If you're after a chassis with an air of premium around it, plus a ton of versatility, and you don't mind the hefty dimensions this beast provides, the Lian Li PC-011-Dynamic is perhaps the ultimate pick. **–ZAK STOREY**

VERDICT **9** KICK ASS!

Lian Li PC-011-Dynamic

NIMITZ CLASS Epic design; easy to build in; brilliant versatility; incredible cooling potential; strong pricing; color variants.

EVER GIVEN Bulky; could use more storage options.

$160, www.lian-li.com

SPECIFICATIONS

Motherboard Support	E-ATX, ATX, M-ATX, ITX
2.5/3.5-inch Support	4x 2.5-inch, 2x 3.5-inch
Max Radiator Support	360mm roof, 360mm side, 360mm bottom
Fan Support	3x 120mm/2x 140mm roof, 3x 120mm side, 3x 120mm bottom
Dimensions	10.7 x 17.6 x 17.5 inches
Graphics Card Clearance	16.5 inches
CPU Tower Clearance	6.1 inches

Many memes, bountiful brilliance.

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Corsair K65 RGB Mini Keyboard

A tiny 60-percent keyboard that makes a big noise

IT'S ALWAYS GOOD when large brands release keyboards that used to be reserved for the enthusiast market. Sixty-percent keyboards have become more popular in recent years, which has brought the price down, because there's more competition. The latest 60-percent board is the K65 RGB Mini, which has all the functionality of a full-sized keyboard, but is far more compact.

The difference is that you must press FN to use the keys that are usually found on larger boards. For example, you press FN-5 for F5, and FN-U, H, J, or K for the arrow keys. If you use arrow keys a lot, consider getting a 65-percent keyboard.

Most of the keyboard works as expected, and during the time we used it, we enjoyed it for the most part. The RGB lighting is always a hit, the double-shot PBT keycaps are nice, and the space bar looks great, especially with the lighting. The layout is also intuitive. Corsair does a lot right, and we don't mean to brush over the positive aspects of the keyboard, but there is an elephant in the room: It's a rather noisy elephant.

Typing on the Corsair K65 Mini makes a horrible pinging noise that reverberates around the case. Usually, a pinging noise is only apparent on certain switches, such as space bar, shift, and so on. With this board, every key stroke induces a pingy noise, and for those with more delicate ears, it's infuriating. Keyboard enthusiasts invest a lot of money in getting a thunky sound stage, and a reverberating ping in a board targeting the enthusiast market misses the mark.

We attempted to dampen the sound by doing some foam mods. We tried high- and low-density foams, as well as different thicknesses, but because it's the switches through the metal mid-plate creating the sound, the noise was only slightly dampened. Even when we tried to clean the keyboard with a soft-bristle shaving brush, you could hear the metallic twanging. It's so frustrating, as Corsair even pre-lubed its stabilizers to ensure that the sound and feel is consistent—and this works very well. We were impressed when we saw this during the keyboard stripdown; a lot of brands don't pay attention at this level of detail.

POLLING OPINION

The board also has an 8K polling rate, which sounds impressive, but with Cherry MX switches, it doesn't really matter that much; the bounce back on a mech switch will likely be slower than the polling rate, which means you're probably held back by that rather than anything else. It might make a difference in the future, or to the esports pros out there, but not today, and not with these switches. With mice, it's a different story, however.

Overall, the Corsair keyboard is a step in the right direction. It's far from perfect, but there are quite a few positives. A 60-percent board from Corsair will bring yet more attention to this adorable form factor and keep the market moving forward. The pre-lubed stabs were a nice surprise, and if it weren't for the reverberation in the case, they're probably some of the nicest feeling stabilizers from an off-the-shelf keyboard. The Corsair iCUE software is also far more advanced than with most other keyboards, and if you've already invested in Corsair products, you'll probably want to stick with its infrastructure. Our advice to Corsair? Drop the 8K polling rate—it isn't needed with Cherry MX switches on a keyboard. Invest the cash in some nicer switches, or even optical ones, add some foam or a more substantial metal case, and look at the switch mounting to get rid of the noise. It is so close to being a hit keyboard, but currently it sits behind many other 60-percent boards we've looked at before. –DAVE ALCOCK

VERDICT **7**

Corsair K65 RGB Mini Keyboard

HITTING TARGETS PBT keycaps; great layout; comprehensive software; vivid lighting; USB Type-C cable.

MISSING THE MARK Hollow-sounding case; really loud reverberting pinging noise while typing.

$110, www.corsair.com

SPECIFICATIONS

Form Factor	60-percent
Switch Type	Cherry MX Mechanical
Switch Durability	100 million
Media Keys	Integrated via FN keys
Connection Standard	Detachable USB-C
Keycap Material	PBT
Weight	1.28lb
Dimensions	4.1 x 11.6 x 1.7 inches

Corsair Sabre RGB Pro Champion Series

Converting the unconvertable

IT'S NOT OFTEN this editor gets to review mice. In fact, at modern-day *Maximum PC*, we tend to leave that particular pursuit to our ex-esports FPS semi-pro player and peripheral aficionado, Dave Alcock. That said, this review came about due to an unforeseen circumstance. Namely, we needed a new mouse. Or rather, wanted one. One in particular: Corsair's M65 RGB Pro.

The M60 line of mice is different from most modern gaming mice. Both in its shape and its weight. The design is bulky, wide, ideal for palm-grippers, and hefty, too. The original M60 Vengeance came in at just shy of 4.2oz (or 118g) without the included weights that you could load it up with. Throw all those extra counters in underneath, and you'd end up with a chunky mouse tipping the scales at 4.8oz (135g) or thereabouts, depending on the version. Couple that with an oddly comfortable yet surprisingly ergonomic grip, and it easily made it a fan favorite among small-handed palm-grippers.

We asked Corsair's PR if they had any kicking around, because we think ours must be trapped somewhere in a cupboard in head office, covered in years of dirt, grime, and abuse. But, sadly, the answer was no. However, they did recommend we take Corsair's latest offering—the Sabre RGB Pro Champion Series—out for a spin instead.

Now, this is quite possibly as far away as you can get from the M60 style of design. It's not a wide mouse and it's certainly not heavy either. In fact, it has been developed (as most things seem to be these days) with esports in mind. Which means that it's super-light, with a top-notch sensor (a Pixart PMW3392), just enough buttons, and all manner of tech wizardry designed to push your super-leet-fragging-death-kill-streak-chicken-dinner-winnings to the max. We think. Probably.

That's not a bad thing either. It features the latest AXON Hyper-Processing controller, meaning that it can be set up with an 8,000Hz polling rate if you so desire. On top of that, it also houses Corsair's latest QuickStrike pretensioning system, effectively eliminating the gap between the Omron switch and the plastic, helping you depress it faster, too. And it's light, as well. Real light. 2.6oz (74g) light, in fact. It's ludicrous; it even comes with a braided drag-reducing paracord cable. The idea is simple: Minimize delay to absolute zero. To get the most out of this, and because AXON's controller means you're sending eight times as much data to the PC as you normally would with a regular controller, Corsair recommends a minimum spec of at least a ninth-gen Intel Core i7 or second-gen AMD Ryzen 7 in your machine when running in 8,000Hz mode. Minimum specs, for a mouse....

GRIPPING STUFF

Ergonomically, it's very similar to what we refer to in the industry as an egg-shaped mouse. Long, slender, slim, with a bit of a bulge in the middle arch to better support the palm. It's also effective regardless of your grip style, although you may struggle if you claw and have smaller hands.

It's almost the antithesis of the M60 in many respects, yet it's brilliant. Taking it out of the box for the first time, it feels as though it almost hovers over your mouse mat, like a puck on an air hockey table. It's a bizarre feeling. It's precise and direct, and amazingly comfortable to palm-grip with. It's also slick, slender, and one of the more aesthetically pleasing mouse designs we've seen for some time. Giving it away for a week to be shot in our photo studio was rough—going back to the Glaive RGB Pro we'd been using previously left us with a sense of longing.

Is it perfect, then? Well, no. It's not for everyone. That said, for what it's designed to do, and how it makes you feel when you first use it, you can't help but think that it's something special, something more than we're used to using. Like the first Razer Deathadder, or the advent of the Logitech G15 gaming keyboard, there's something magical about this. –ZAK STOREY

VERDICT **9**

Corsair Sabre RGB Pro Champion Series

DAMASCUS STEEL Impeccable sensor; strong design; super-light but not too light; iCUE impeccable; strong pricing; rapid response times.

RUSTY IRON CPI indicators; not ideal for fingertip/small claw grip; minimum specs.

$60, www.corsair.com

SPECIFICATIONS

Sensor Model	Pixart PMW3392
Max Sensitivity	18,000 cpi
IPS	450
Programmable Buttons	6
Weight	2.6oz (74g)

Creative SXFI Gamer

Creative's bold shot at a competitive gaming headset

CREATIVE HAS always been a solid competitor in the digital entertainment sector, offering products for a wide range of audiences. Having spent a long time in the audio market, the company certainly claims a lot with its SXFI Gamer headset. It says, for gaming, it sounds like you've been dropped into a battlefield, for music it sounds like you're at a live concert, and movies sound like you're in a theater (remember those?). These are bold statements, considering the price of this headset alone sits more toward the budget end of the spectrum. Are Creative's statements backed up, or are they just lures to pull in new buyers?

From the price point, we weren't expecting premium materials, but the quality isn't bad by any stretch. Although it can feel a little light, creaky, and plasticky, the comfort is great for long stretches of gaming. There is little stress on the head, but more padding on the headband would be a nice addition. The cups are very well cushioned and do a good job of surrounding your ears without creating a lot of pressure. The headset has a sleek matte black finish, which is always going to be a timeless look. Of course, more metals and premium materials are always appreciated, but it's a comfy pair of cans for the price.

All the controls can be found on the left can, with the right can being blank. On the left side you get a button for RGB control, a feature that's only available when you have the headset plugged in via USB using the USB C port, found on the right can. The other form of connectivity is our good ol' favorite, the three-pole auxiliary jack. You get a volume wheel as well, and a mute button beneath that. An announcer's voice confirms what you've changed on the headset, so you're not messing around for ages trying to figure out what you've pressed. A cool touch.

The headset also comes with a detachable microphone, called the CommanderMIC. It's well constructed, with a metal grille design and integrated red light that stays on when you're live and flashes gently when you're on mute. For the best pickup, we found that the LED needs to be facing your lips, as it can differ vastly with only a slight movement of the mic. Saying that, the audio quality is very good. It has a strong bass pickup while maintaining clarity.

The other main feature is again only accessible through the USB connection, and that's the SXFI button (or sound mode button). There are technically three modes: SXFI, Battle, and off. SXFI mode attempts to expand the sound stage, so you can hear much more detail. In more generic terms, it's the surround sound mode. This is an impressive bit of virtual surround sound, or as Creative calls it, "7.1 holographic audio." It does a good job of creating extra immersion in media such as shows or movies, but with music, it can feel like a big-room sound effect, as it tends to echo. When listening to music, the best choice is to have all modes off. This standard mode offers a neutral all-around sound package. It performs best in the mid-range, but suffers toward the high end, with a slight lack of clarity. The cans are decent for bass, too, but a little more would give this pair a warmer sound. Battle mode is the last option available on the SXFI Gamer, and it certainly does what you'd expect. For FPS titles, in particular, this gaming-focused sound mode is great for directional awareness, key for competitive environments. It's almost pinpoint accurate, and gets a big thumbs-up from us when it comes to gaming.

If you're after a decent gaming experience, Creative's SXFI headset will certainly be more than good enough, especially at this price. Although it's not brilliant in all areas, such as music consumption, and doesn't feature premium materials, the gaming appeal alone is an excellent selling point. With good comfort, compatibility, and accurate directional audio, this is a strong headset from Creative. –SAM LEWIS

VERDICT **8**

Creative SXFI Gamer

CHICKEN DINNER Pinpoint directional accuracy; lightweight build; clear mic quality; immersive gaming sound.

360 NO SCOPE Cheap materials; not wireless; music can sound a little flat.

$130, www.us.creative.com

SPECIFICATIONS

Driver Type	50mm neodymium magnet
Frequency Response	20-20,000Hz
Impedance	32 ohms
Connectivity	3.5mm jack, USB C
Design Style	Closed-back

SteelSeries Rival 3 Wireless

Wireless freedom and long battery life—isn't that all you really need?

FIRST, A CONFESSION. We've used a few wireless mice in our time, but we have never spent quite so long searching for the USB dongle that connects one to our PC. Over and over we turned it in our fingers, pausing to admire its matte black finish and nicely slick pads while we did so. However, we found no evidence of a little door to release the dongle. We couldn't even find where to put the batteries in.

A quick check of the box revealed no instruction leaflet to put us on the right track, just an assurance that the dongle and two AAA batteries were included. We shook the mouse—nothing, no rattle, no cries of the imprisoned. It was starting to look like we'd have to use Bluetooth to connect it, and nobody likes that. The mouse looked up at us from the desk, mockingly, the slight gap where the buttons meet the back of the casing appearing to crinkle into a derisive smile.

Eureka! Applying a small amount of force to that gap slides the casing off, revealing slots for both batteries and dongle—all filled. Transferring the dongle to a vacant USB port on our PC, and flicking the switch on the bottom of the mouse to the 2.4GHz setting (the other options are off and Bluetooth), we instantly had pointer movement. Windows found the driver immediately and, neatly, a popup prompted us to install SteelSeries's Engine 3 software, which served up a firmware update straight away, so we could customize the lone RGB zone (the wheel) and the button configuration (there are six).

The Rival 3 Wireless is a modest mouse; there's nothing to break its matte black coloring apart from a gray logo and that RGB wheel, the buttons sitting close to its body and not drawing too much attention to themselves. And that's a good way to describe the whole package: It's a low-slung device that will feel small to the large-handed or anyone used to the larger Logitech or Razer models, and with minimal buttons and RGB, there's nothing here that stands out.

Nothing, that is, apart from the battery life. The packaging claims you'll get a year out of a pair of AAAs, a bold claim we've so far been unable to test, having had it only a few weeks. Elsewhere on the box the figure is 400 hours—50 days at eight hours' usage a day. There are battery-saving settings in the Engine software, including one that turns the wheel light off when the mouse is moving, a sleep timer that turns the mouse off after five minutes of inactivity (and can be set to between one and 20 minutes), and some mysterious High Efficiency Automatic Settings that seem to drop the polling rate to 125 Hz and put the sensor into an allegedly more power-efficient mode. Swinging the pointer around the desktop on a 4K screen, we couldn't really tell the difference, apart from noticing that the wheel light was permanently off.

Then there's the side buttons. They're very small, and lie flat to the casing. It's perfectly possible to find them with your thumb when wanting to flip back and forward through web pages, but gamers may wish they were raised further if they're using them for last-second grenades or mission-critical weapon switching. The mouse is also back-heavy, thanks to the position of the batteries, meaning that although it's a perfect fit for a claw grip, you can guide it with a finger on the wheel just as easily. And it is a particularly nice wheel, the feel judged just right as each click of its rotation clunks into place, the feedback loop between its jerky circumductions and the motion of lines of text on your screen easily established.

For a cheap mouse, it does all you need, with the bonus addition of wirelessness and long battery life. There's nothing here to particularly shout about, but it should keep any user happy until at least its first battery change. **–IAN EVENDEN**

VERDICT 8

SteelSeries Rival 3 Wireless

ENDURE Long battery life; six programmable buttons; dash of RGB.

UNSURE Side buttons a bit small; no stand-out features.

$50, www.steelseries.com

SPECIFICATIONS

Sensor Type	Optical
CPI	100–18,000
Acceleration	40G
Polling Rate	1,000Hz
Buttons	6
Click Rating	60 million
Weight	3.7oz with two batteries
Length	4.7 inches
Width	2.3/2.64 inches (front/back)
Height	0.85/1.49 inches (front/back)

Creative Sound BlasterX G6

Can this external DAC blast its way into your life?

CREATIVE'S SOUND BLASTER soundcards are a key element of its success and helped cement the company's high standing in today's audio world. Since 1989, it has been the de-facto standard for PC audio, and that's something to hold on to with great pride. Fast-forward to 2021, and Creative is still using its Sound Blaster brand to push the idea that high-quality audio is vital to your overall experience when consuming media.

The Sound BlasterX G6 falls into the portable part of this legacy and brings in a different audience, focusing on improving their gaming experience. Creative claims that "the G-Series of portable and external USB DACs and amps are must-haves in your quest to up your gaming edge" and they are for use with PlayStation, Xbox, Nintendo Switch, PC, and Mac, which makes them pretty much universally compatible. Has Creative achieved this goal with the BlasterX G6, and can you achieve audio quality highs with a portable in-between device that fits in your pants pocket?

The little-bitty G6 has massive ease-of-use appeal. Straight out of the box, you can see how portable this device is—it's a little smaller than a smartphone, for perspective. Normally, a traditional DAC setup is a wall-powered device that stays plugged into your setup. The G6 offers on-the-go performance, which you can take anywhere, especially if using it with a gaming laptop.

The design itself is influenced by the gaming scene aesthetic. It's a sharp and sleek-looking device, finished in a gunmetal gray plastic chassis. A black stripe runs down the middle, with an illuminated Sound BlasterX logo. Its base is slightly rubberized, which is supposed to stop it from sliding all over your desk, but it's very light, which makes it harder to stick down. The benefit of this, of course, is its portability factor. Despite the lightweight nature, though, it's a well-constructed, durable product.

On the G6's face, you'll find a volume dial in the center, 3.5mm headphone jack on the left, and 3.5mm microphone input on the right. The dial is perfectly weighted and smooth, allowing for precise volume adjustment. It's also backlit, adjusting to the current volume, and acts as a mute button when pressed. If you hold it down for two seconds, it switches the control between playback volume, Sidetone mic volume, and GameVoice mix. On the back, you have a micro-USB port, used for PC, PS4, or Nintendo Switch. For other devices that don't connect via USB, this port is used for power delivery. Next to that are the line/optical in and out jacks. To connect an Xbox One, Blu-ray player, or media player, for example, you would have to go down this route. Down the right-hand side of the G6, you can find the Scout mode, SBX, and gain slider.

RE-SOUNDING SUCCESS

The G6 features an Xamp discrete headphone bi-amp, which helps with directional audio in gaming. It sounds complex, but in simple terms, it amplifies each channel individually, instead of amplifying both at once using the same amplifier. For instance, if you have a spray of bullets coming past your left shoulder, that's the channel it amplifies. The Sound BlasterX mode (SBX) does an all-around job of cleaning up the sound and amplifying it; sounds are richer and the bass is more intense, so for general usage, casual gaming, and media consumption, this is a great mode to pick. If you're looking into the competitive side of gaming, Scout mode is now your new best bud. The details it pulls out of games is impressive. It really brings focus to your gaming experience. The details are amplified massively, giving you a great audio awareness advantage over competitors. Not to mention the increased sound quality. With the additional Sound Blaster software, you can extend these EQs, personalizing them to your exact taste.

As a small portable package, the G6 excels in improving all sorts of gaming devices, with strong compatibility, decent style, functionality, build quality, and, above all, a great sound stage. Its only let-downs are its plastic build, the fact that it slides about a bit, and its micro-USB port instead of USB C, but that's just us being picky. One thing to note: Take care of your ears and headphones, as this device can push out some serious power. It's a fantastic little gaming DAC/amp and USB soundcard, which improves your audio quality across a multitude of devices. If you need to amp up your setup and up your game, the Sound BlasterX G6 is a great companion. –SAM LEWIS

VERDICT **9**

Creative Sound BlasterX G6

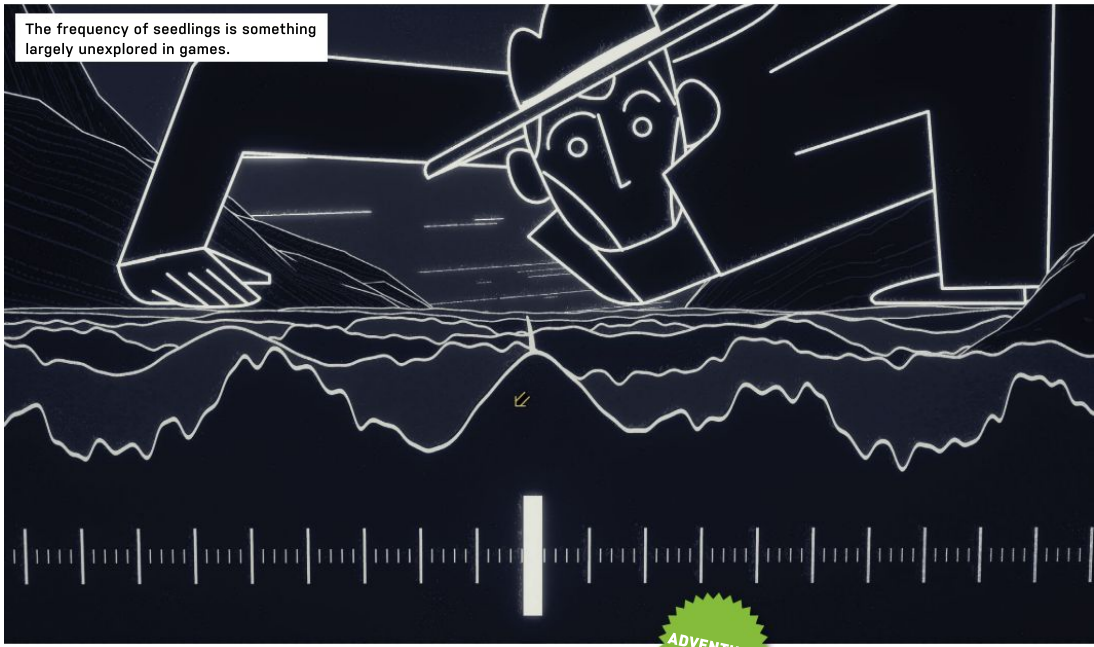
FLY LIKE A G6 Great sound stage; plug and play; great compatibility; must-have audio companion.

CRASH AND BURN Plastic body; no USB C; needs a grippier base.

$219, www.us.creative.com

SPECIFICATIONS

Audio Quality	130dB DNR
DAC	32-bit/384kHz
Amp Output Impedance	1–600 ohms
Features	Virtual 7.1 surround, discrete 5.1 surround, discrete Xamp headphone bi-amp, Dolby Digital decoding
Connectivity	3.5mm jack, 3.5mm mic input, micro-USB, line/optical in and out
Dimensions	0.9 x 2.7 x 4.3 inches
Weight	0.3lb



The frequency of seedlings is something largely unexplored in games.

ADVENTURE GAME

Genesis Noir

Change destiny and save your love. But at what price?

WE'RE KNEELING on the ground, adjusting something like the dial on an AM radio to tune in on the frequency that will make a plant grow. We've been planting seeds for some time, absorbing different kinds of energy and crossing tendril-like bridges. We've spun a flower to turn it into a kind of star, and rotated the heavens faster and faster to make time pass—swirling the mouse on our desktop in a way the manufacturer of our mouse pad never envisaged. We're here because, after selling watches on the street, we saw a woman get shot, and time stopped. It's all very confusing.

That woman was our lover, Miss Mass, first name unknown. She's a singer but doesn't say much, and she has a body built for just one thing: the gravitational attraction of anything that comes close. Swept up in her orbit is Golden Boy, quiffed musician and bilateral force of creation and destruction. It's a love triangle that can only end in one thing: four-dimensional spacetime.

Genesis Noir is somewhat difficult to categorize. The "Noir" part refers to the presentation, a murder mystery investigated by No Man—a private detective in a hat and sharp suit, who lives in a clock. The saxophone soundtrack honks and wails, and you expect a broad who looks like trouble to enter your office at any moment, lighting a cigarette and relaying a hard-luck tale that's bound to end up with a rooftop shoot-out at midnight. The "Genesis" part takes on not biblical creation—though there are references to and appearances from gigantic watchmakers, serpents, and apples—but its scientific mirror, the Big Bang.

Murder and creation. And you're there at the beginning of both: Golden Boy's pistol shot, which sets the game and the universe in motion, a moment caught in time. From there on, it's a surreal ride. The game looks like nothing else we've encountered—though there are hints of *Grim Fandango* (a shop called Manny's Musical Instruments can't be a coincidence)—and sounds unique, too, its constant blowing sax, fretless bass, and skillful drumming the background to, well, what exactly? Games have attempted noir before, of course, with Max Payne shoot-dodging his way across the genre with a gritty monologue, and *BioShock Infinite's* DLC going straight in with the private investigator and dame to kill for tropes. This is nothing like either of those.

WORLD APART

You are definitely in control, but your role is a limited one, and the majority of your time is spent watching the world around you unfold and marveling at it before spamming the pointer everywhere in search of the interactive. It's a rare game that makes it difficult to choose representative screenshots to accompany a review, but *Genesis Noir* constantly offers up new vistas and scenes that you think can't be beaten, only to smash them with something newer and better within the next five minutes. Nothing is representative because nothing stays the same.

You push No Man through the world, holding on to his hat as he runs,

© FELLOW TRAVELLER

Golden Boy seems awfully large at first, but perception can be changed.

Black holes and other cosmic phenomena are nothing to be afraid of.

sometimes pausing to free birds from a tree or dip the roots of young plants in an underground river of light, but as you have no idea what could possibly be coming next, it's without greater purpose—you go forward just to go forward. Luckily, the game constantly rewards you with new sights, even the soundtrack getting in on things to drop hints as to how close you are to a solution before becoming part of the playset itself, allowing you to drop new notes in with a click of the mouse. Your actions have constant consequences, and the feedback you receive from the world becomes more important than your progression through it.

Despite the constant delight at the novel things the game asks you to do and see, there's a paucity of interaction here that makes you wonder whether the concept would have been better realized as a movie—a largely monochrome, silent one, accompanied by a live jazz band. There are other colors in this world, but they are used sparingly—golds and midnight blues that serve to accent and enhance the scene rather than dominate it. You chase down a stream of yellow energy bubbles, and watch a cosmic figure play a flaxen sax, picking the instrument up yourself to play call-and-response with a double bass player. We're very glad the devs chose to make this a game, because it suits the constant thread of creation that runs through it. If we had to, we'd call it a point and click, because you'll do both of those things, even if your movement is better off as keyboard-driven.

Getting hands-on with abiogenesis, slotting amino acids together like Legos, underlines the toy-like nature of the game. It's never very difficult and isn't particularly long, either. With its anthropomorphic representations of time and mass, as well as dimensions, black holes, and the expansion of the universe, it's even possible to learn something from this, though your high school science teacher might not be impressed if you cite it in a paper.

The greatest single thing about *Genesis Noir*, however, is the imagination that has clearly been liberally poured into it, and the way the game celebrates this. There's not much in the way of replay value here—although you may wish to load it up just so you can say "Look at this!" to any friends as yet unsold on the virtues of PC gaming—but it's a cheap one-way ticket to spectacles we certainly haven't seen before. Only one question remains: When faced with a number scrawled on a napkin, do you know how to operate a rotary-dial telephone? –IAN EVENDEN

VERDICT **9**

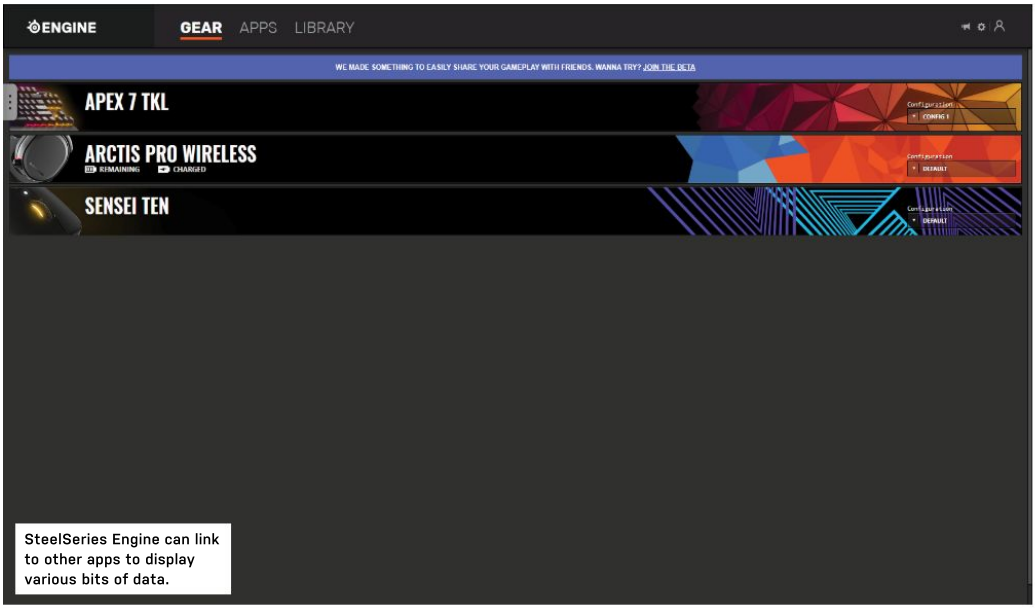
Genesis Noir

RAYMOND CHANDLER An adventure that looks and sounds like nothing else we've played.

CHANDLER BING Sags a bit in the last third; sometimes feels more like an interactive movie.

RECOMMENDED SPECS 2.6GHz or higher CPU, 6GB RAM, GeForce GTX 560 Ti or newer.

$15, https://genesisnoirgame.com, Not rated



SteelSeries Engine can link to other apps to display various bits of data.

SteelSeries Engine vs. Corsair iCUE

HEAD TO HEAD

A battle of the peripheral software; is one really better than the other?

WHEN WE REVIEW a product, we look at the software as well as the hardware. Sure, most peripherals have good functionality without having to install anything, but if you want to unlock their full potential, installing the software suite is advised. In this head-to-head, we're going to look at the two software suites we seem to get on with the best: Corsair iCUE and SteelSeries Engine 3. This isn't to say that software from other brands is not up to scratch (Razer's Synapse is another standout), but these two are our current favorites.

Corsair iCUE comes in at a hefty 741MB for its latest version. Corsair has all the usual macro controls for keyboards, mice, and headsets, and with the acquisition of Elgato, you can actually integrate the Stream Deck with it, too, so you can create some crazy lighting scenes at the touch of a button. If you want to control your Philips Hue products with iCUE alongside this, no problem. With Corsair having far more hardware than SteelSeries, there is a lot more to control. Corsair manufactures power supplies, RAM, coolers, cases, custom loop products, and more, and the majority of it has some type of control via iCUE, even if sometimes it is just lighting.

The software can also perform real-time monitoring of hardware. This enables you to get statistics for temperatures, CPU load, RAM monitoring, and other metrics. We're not talking about just Corsair products either. We were pleasantly surprised when we opened iCUE on one of our test systems and our Nvidia RTX 3080 FE popped up on the home page. From here, we were able to control the two lighting zones, check the temperature, and set up temperature alerts. Our Asus motherboard also showed up, although it was only the lighting that could be changed. Having everything in one place is certainly a far better solution than needing to install numerous RGB lighting software suites, which often conflict with one another. Some motherboard brands have terrible RGB control, and if there is one thing Corsair can do well, it's making your computer look as though it's devoured a unicorn. All the lighting can be linked, as well, so you can change the colors of everything in your setup, including your Hue lights, at the click of a button.

You can set multiple profiles with iCUE, which is particularly handy if you want to have a keyboard layout for work but would like something different when you're gaming or writing, and it's easily done. The same goes for different fan profiles if you're using the Corsair fan systems.

STEEL YOURSELF

Compared with iCUE, SteelSeries Engine is tiny at only 163MB, but it also offers far fewer features as a whole. SteelSeries Engine is very powerful when it comes to controlling the company's peripherals,

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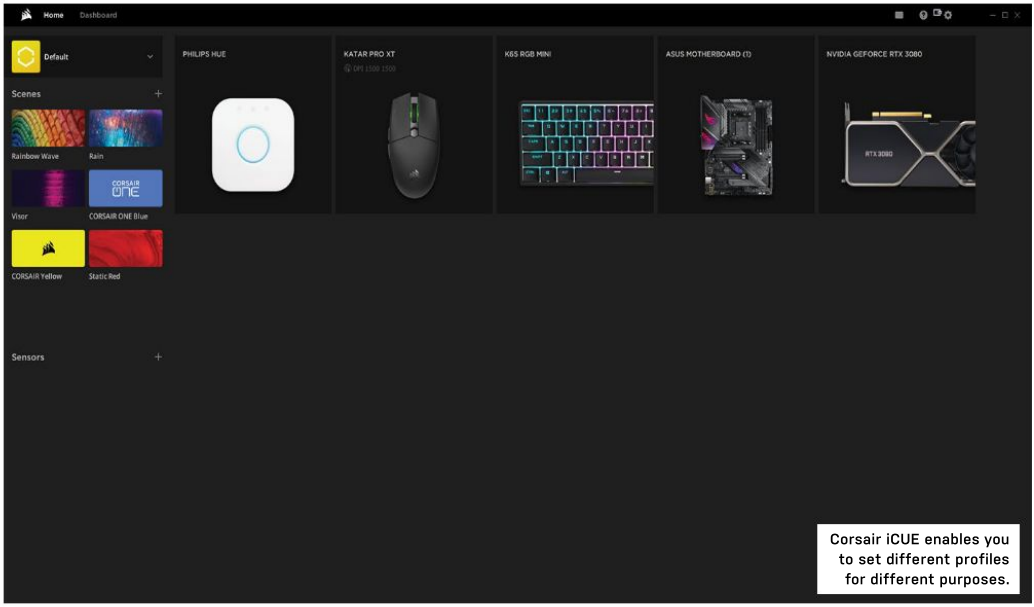

Corsair iCUE enables you to set different profiles for different purposes.

offering some features that surpass those of its competitors. For example, on smaller keyboards, the way SteelSeries deals with multiple function options is far more intuitive and easier to use overall. The SteelSeries Engine also feels more tailored toward being able to show information on the OLED screens that are incorporated into some of SteelSeries's products. Some of the apps available for the screen are great, especially the ones made by users. One of our favorites is the Spotify app, which enables us to see at a glance what song is playing on our mini keyboard screen.

SteelSeries Engine can also be seamlessly integrated into games and other applications with the public SDK. For instance, if you're tagged in a post on Discord, you can have your keyboard or mouse flash a different color. If you are muted, you can make your headset red, and so on. At the moment, there are limited apps and games that take advantage of this directly from the software itself, but user-generated apps continue this further. In the future, SteelSeries is going to incorporate a feature similar to Nvidia Shadowplay, called Moments. This is currently in beta, but the general idea is that when something happens in game, you can press a hotkey, and SteelSeries will take and save a clip of what happened. You can then edit the clip within SteelSeries Engine and share it via multiple platforms. Pretty impressive stuff for gamers, but it has limited usefulness outside of the gaming environment—a common theme with SteelSeries Engine that isn't mirrored in iCUE. We're not sure if it's because there are far fewer features and items to control via SteelSeries Engine that it feels a little more user-friendly overall, but it generally has a more instinctive feel to it, especially when you're trying to show someone how to use it. That's not to say Corsair's software is particularly confusing, it just takes a little more time to learn how to use its full power.

The main takeaway from this head-to-head is that, like many other things in the peripheral sector, choice of software is very much personal preference. Having said that, there are some noticeable differences. If you're just looking for powerful software that's centered around gaming, while still wanting the ability to incorporate OLED screens and apps, SteelSeries Engine is the way forward. If you're looking for a more comprehensive software suite that can not only control your whole Corsair ecosystem, but also monitor other hardware, control lighting, and more, Corsair would be the way to go.

One thing to note is that these two products are there to try to lock you into the brand, and this is the same with all current software suites. If you want to link your lighting across your keyboard, mouse, headset, and so on, you must buy products bearing the same logo. We would love for this to change in the future, and Corsair is currently taking some steps in the right direction, but the cynic in us can understand why it isn't a pressing matter for companies, where profit is king. For those who do want different brand peripherals, we suggest just installing the software you really need. –DAVE ALCOCK

VERDICT 9

SteelSeries Engine

V8 Slick interface; nice design elements; SDK pack; easy to use; small file size; better keyboard remapping.

4 POT No cross-brand compatibility; smaller product stack.

RECOMMENDED SPECS Windows 7 or newer.

$Free, www.steelseries.com/engine

VERDICT 9

Corsair iCUE

TESLA MODEL 3 Vast product stack; compatible with other companies' products; strong design elements; easy to use.

CHEVY VOLT Huge file size; keyboard remaps still need work.

RECOMMENDED SPECS Windows 10 64-bit, 1.5GB HDD space, Z170/X99, AMD FM2/AM4, or newer.

$Free, www.corsair.com/us/en/icue

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LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Of Splodges and Men
> AIB Cards
> Intel's Next Gen

The Heck Is a Splodge?

Greetings esteemed editor. The "Budget Buster" feature in the April issue is an outstanding example of intelligent analysis of the elements of a computer, and a demonstration that price is not the ultimate criterion! Such a paper offers proof of the high quality of the journal.

However, perhaps because I live in a foreign country, Québec (presently part of Canada), which uses the metric system, I am confused by the exact measurement described by the term "splodge."

Is this a metric measurement, officially identified by a quantity of thermal paste kept in a test tube at exactly 25 C at the National Science Council, and named, perhaps, after the eminent Senator Henry Cabot Splodge? I suppose a centisplodge and a millisplodge are used for different models of PCs.

Given that the US still uses the ancient English units, such as miles, yards, and football fields, I wonder nevertheless if the splodge is one of those old units. Perhaps the basic unit is the dab, equivalent to the weight of the toenail clippings from the left foot of King Henry VII of England (and Wales)? Seven dabs would be a gob, and 6¾ gobs would be a splodge, or a short splodge, 8½ being required for a long splodge, used mostly in calculating shipping costs?

A private response is not expected, but perhaps a future issue might include an explanatory note!

–Pierre Corbeil PhD

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: Ah, that age-old argument, imperial versus metric, the US and UK versus the world. Would you believe that I grew up with both measurement systems, due to a ridiculously multicultural family that has moved around the world far more often than Gandalf called in the eagles for help, so can use and convert between the two systems at will? I know it's weird. Not helped at all by PCs, where we use millimeters for fan and radiator dimensions, psi to check liquid-cooling pressure, Celsius for temperature management, and "slots" for graphics card compatibility. Personally, for speed I use mph, for my cardiovascular training I use km, for my height I use cm (because I'm 5' 8.5", but if I tell people that, they just think I'm compensating for being short), for my weight I use both pounds and kg, and for building furniture I use mm. It's a mess, but I can swap quite easily between all that. I'll admit, though, even I have no capacity to translate the Gregorian calendar and standard time into metric time; that's an insane step too far for me.

I'm getting side-tracked, but I find the world of measurement systems and how we got where we are genuinely fascinating. A YouTuber I follow, Joe Scott, did a fantastic video called "Why Don't We Have Metric Time?" where it goes into detail about the various ways we've had to measure things over the years, and it's an eye-opening watch (https://bit.ly/3tOfcCY).

Anyway. Splodge. A splodge is like a smidge, or spudge, or pinch, and is a shorthand way of saying sploodge, mostly defined by its onomatopoeic properties, rather than any one direct measurement. It's actually an old British word, according to the research I could find, derived from splotch, which in turn was a mixing of spot and plotch from the 17th century. Plotch fell out of favor, but spot comes from the Middle Dutch/English word *spotte* from the 15th century, and dates back even further to the Old Norse word *spotti*, meaning "small piece." So a splodge is a small wet piece defined by its physical characteristics. Basically, I got fed up of using the same old tired metaphors to describe how much thermal paste you need, "half a grain of rice" being the most common, and tried to jazz it up a bit with an uncommon antiquated word. So, use a splodge, small grain of rice, of thermal paste for your standard-sized CPU (LGA1150+/AM4).

Thank you for this letter. Times are tough, and it cheered me up on an otherwise rough day.

Aftermarket GPUs?

Hi Zak. Let's pretend you can buy a GPU. Does it

↘ submit your questions to: comments@maximumpc.com

matter which one you get in a certain series? Aftermarket partners? More expensive models? What's the difference? I don't understand. **–Tim M**

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: This is a good question, and something I was talking with Sam about the other day. When it comes to graphics processors, or GPUs, they're only made and designed by the two big manufacturers Nvidia and AMD. And most of the time they outsource manufacturing to TSMC, Samsung, and a few other semiconductor companies. Those guys manufacture the chips from the silicon. These chips are then sold on to third parties and handed back to Nvidia and AMD as well, so they can be incorporated into cards.

Now, similarly to Intel and AMD processors, the quality of the silicon that the chip is cut out of determines the characteristics and personality of that processor. Basically, not all chips are equal; some perform better, while some have errors (such as non-working cores—these are typically downgraded and sold as a lower-cored processor, as an example), and some perform far better than Nvidia, AMD, and Intel's base parameters—those parameters are typically designed with reliability in mind first and foremost.

What aftermarket partners do is buy a batch of these chips—a batch of RTX 3080s, say—then test each individual GPU chip, identify which chips are likely to perform best, and then, depending on how they do, place them in various cards within their lineups. These AIB (add-in-board) partners can design their own custom cards, complete with different power delivery, different layouts, cooling, and even their own VBIOS, to maximize the performance from these pre-binned chips. This way, they can bump up the voltages and speeds of the processors comfortably, still provide a decent warranty, and charge you more for the privilege.

As an example, the lowest-end MSI RTX 3080 card runs at 1,725MHz, whereas the top-end SUPRIM X version runs at 1,920MHz at stock—about 11 percent faster overall. That's not directly going to translate to 11 percent more performance, but it will perform faster than the reference card.

So, in normal times, you can pay slightly more to guarantee you'll get higher clock speeds, and you'll know that these chips are potentially even capable of more than that. However, if you buy a stock card from Nvidia or AMD directly, these chips often aren't binned, and depending on how good your luck is, you could end up with a card that clocks as high as a pre-binned card for a lower price. Pop a waterblock on top of that, and all of a sudden you've got a flagship card for a couple of hundred dollars less.

[NOW ONLINE]

WINDOWS 10 PRODUCTIVITY TIPS AND TRICKS

Your PC is nothing without its operating system, and for most devices (about one billion, to be more precise), that OS is Windows 10. Windows has been around for so long that even the technologically inept should be able to find their way around the latest version. But if you're a tech enthusiast, you don't just want to be able to use Windows 10; you want to master it. Then can you enjoy the performance your system was built for and make the most out of what your PC, the ubiquitous OS, and you can do.

We've been detailing some of the handiest Windows 10 tips and tricks, so you can maximize your PC's relationship with the OS, and make sure it works the way you want it to with your device. This means tips on maximizing Windows 10's productivity software, momentous hacks that are sure to boost your productivity, troubleshooting tutorials to keep in your back pocket, and even answers to questions you're too scared to ask.

Read the full article here: https://bit.ly/MPCWin10

Intel's 10nm Chips

Hi *Maximum PC,* Given everything that's going on in the processor world, why can't Intel break past 14nm? What's going on? Love the work the team does, but I want to see more advanced builds again! Bring back liquid-cooling and Dream Machine. **–Rob A**

EDITOR-IN-CHIEF, ZAK STOREY, RESPONDS: Hi Rob, this is a tough one. Obviously, Intel has been stuck in limbo now with 14nm for a long, long time, almost as long as I've been in tech journalism, in fact. 11th gen is the seventh generation of 14nm chip, if you include Broadwell, and there were five generations of the Skylake architecture before that, too, so it hasn't been a particularly comfortable time for Intel, that's for sure.

The good news is that, as far as we can tell, Intel should be releasing 12th gen some time this year, complete with some architecture tweaks and, more importantly, a 10nm manufacturing process, which should bring it on par with AMD's 7nm for size, and maybe even performance.

We're still not sure whether that'll put it on a core-for-core parity with Team Red, but as far as single-core goes, that should lead to some significant improvements over this current generation, as Intel is definitely behind right now.

Jarred's currently writing us a pretty in-depth feature for next issue on the Rocket Lake architecture—how it works, and what's next for Intel, given AMD's dominance, so hopefully that will give us all (myself included, because Jarred is a tech wizard) some much-needed knowledge about the whole situation.

I'm fairly tech-agnostic when it comes to these parts (as you can probably tell during my tenure at the mag), so I flip-flop a lot between AMD and Intel. However, even I've got to say I'm rooting for the underdog here. Competition is really needed in this industry, and I know AMD has promised it won't rest on its laurels, as Intel did for a good six years, but the mind does wonder whether they could get a bit more out of their mainstream chips.

What I really want, though, is room for maneuvering when it comes to tinkering. Right now, overclocking is effectively dead. Because both Intel and AMD are pushing their chips to the max in terms of frequency, voltages, and automated overclocking tech, there's no room for folk like me to try to eke out some extra performance. I know it's a niche hobby, but I miss the days of overclocking my Core i5-2500K to 5.4GHz on a single rad, and things like that.

THE BUILDS

THIS MONTH'S STREET PRICES...

WE'RE NOT SURE if we should be celebrating the fact that scalper prices are finally coming down with these graphics cards, but, er, scalper prices are finally coming down with these graphics cards—so, yay! Instead of being near three times the RRP, they're now only twice as expensive, at least with the RX 6700 XT; the RTX 3060 is still three times the price, but it's down from last month. We have a hunch that the only folk buying these cards at these prices are scalpers, trying to make a quick buck, but because the demand is decreasing as the cryptoboom seems to be easing off slightly, the prices for these GPUS are falling, too. It's a slow meander down, sure, but it does look promising.

At the time of writing, the value of Bitcoin has also tumbled by 6 percent overnight, as the Biden administration has announced potential tax changes for high earners, which will no doubt also have an effect. As demand for mining falls, due to the volatility of some of those coins, availability and reasonable prices for GPUs are likely to become more commonplace as well.

We haven't changed too much otherwise across the two builds—motherboard and memory prices are still slowly creeping up, so we've had to go for the cheapest compatible parts we could find, and we've swapped out the two power supplies from last issue for two shiny new 500W models: one from EVGA, the BA (an upgraded variant of its long line of solid budget PSUs, namely the BQ and BR), and a lovely Seasonic number, a brand we don't feature enough.

We're still waiting on Intel to release its lower-end processors in its 11th-gen lineup, but once it does, the Core i3-11100 or 11300 with Intel Xe graphics (if the company goes that route) could be a potent budget gaming chip. The same goes for AMD—we're also expecting to see a new series of Ryzen 5000 chips with integrated graphics, similar to the current chip we're recommending, but based on the Zen 3 architecture.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	500W EVGA BA 80+ Bronze **NEW**	$35	
Mobo	ASRock B450M-HDV R4.0 **NEW**	$72	
CPU	AMD Athlon 3000G	$80	
GPU	AMD Radeon RX 6700 XT 12GB **NO STOCK**	$480	$975
RAM	16GB (2x 8GB) Geil Evo Potenza @ 3,000MHz **NEW**	$72	
SSD	250GB Samsung 980 Pro M.2 PCIe 4.0	$80	
HDD	1TB Seagate Barracuda 1TB 7200	$46	
OS	Windows 10 Home 64-bit OEM	$32	
Approximate Price:		**$992 or $1,487**	

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	500W Seasonic S12III 80+ Bronze **NEW**	$42	
Mobo	MSI B460M PRO **NEW**	$92	
CPU	Intel Core i3-10100	$115	
GPU	Nvidia GeForce RTX 3060 12GB **NO STOCK**	$330	$950
RAM	16GB (2x 8GB) OLOy WarHawk RGB @ 3,000MHz **NEW**	$73	
SSD	250GB Samsung 970 Evo Plus M.2 PCIe 3.0	$60	
HDD	1TB Seagate Barracuda 1TB 7200	$46	
OS	Windows 10 Home 64-bit OEM	$32	
Approximate Price:		**$885 or $1,505**	

SIMILAR TO OUR BUDGET BUILD, we've once again seen prices fall in the scalper market, suggesting that the cryptoboom might be slowing down. It's not quite as dramatic as the budget build (where we saw prices fall by $200 per card), but it's still enough to make us hope for a better future, and not be tied to the inevitable randomness of Newegg Shuffles. GPU situation aside, we're still seeing the slow creeping up of memory prices. We've decided to stick with the same kits as last issue for these two builds, but both prices have gone up by around $5, which is worrying, to say the least.

The biggest change, however, is with the Intel build: We've bitten the bullet and gone for the latest 11th-gen processor, in the form of the Core i7-11700K. Unlike the i9-11900K, which was missing a few cores, the 11700K packs the full complement of eight cores that its predecessor series had, but with added PCIe 4.0 support and a big boost to single-core IPC performance, which makes it an obvious upgrade. It's also given us the chance to swap out the SSD.

If we're honest, for the Intel system, we'd actually recommend you buy the Sabrent Rocket 4.0, as featured in the AMD build, but the Corsair Force MP600, with its hefty heatsink, is a good alternative if you're not quite sold on Sabrent just yet.

Frustratingly, motherboard prices have jumped a bit for the Z590 series, so we've gone for one of the cheapest boards we can get (that won't make the PC-O11-Dynamic look as empty as a pandemic-closed concert hall). There is an Asus M-ATX board that's slightly cheaper, the Prime Z590M-Plus, but we're talking $5 difference.

As for our AMD build, stock is still looking scarce for fifth-gen chips, and our pick from last issue, the Ryzen 5 3600, is now out of stock, pushing us to get the slightly pricier 3600X instead. We're hoping to see AMD drop a new generation of processors later this year, but, well, it's anyone's guess as to what availability is going to look like with that.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$150	
PSU	650W EVGA SuperNOVA GA NEW	$80	
Mobo	ASRock X570 Phantom Gaming 4S	$140	
CPU	AMD Ryzen 5 3600X NEW	$250	
Cooler	240mm Cooler Master Masterliquid ML240L RGB NEW	$50	
GPU	Nvidia GeForce RTX 3070 8GB NO STOCK	$500	$1,600
RAM	16GB (2x 8GB) G.Skill Ripjaws V DDR4 @ 3,600MHz	$90	
SSD	500GB Sabrent Rocket 4.0 M.2 PCIe 4.0	$90	
HDD	1TB Seagate Barracuda 1TB 7200	$46	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $1,428 or $2,528

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$150	
PSU	650W Be Quiet! Straight Power 11 NEW	$125	
Mobo	MSI Z590-A PRO NEW	$180	
CPU	Intel Core i7-11700K NEW	$390	
Cooler	Enermax Liqmax III 240 ARGB NEW	$64	
GPU	AMD Radeon RX 6800 XT 16GB NO STOCK	$650	$1,550
RAM	16GB (2x 8GB) Corsair Vengeance LPX @ 3,600MHz	$95	
SSD	500GB Corsair Force MP600 M.2 PCIe 4.0 NEW	$100	
HDD	1TB Western Digital Caviar Blue 7200	$46	
OS	Windows 10 Home 64-bit OEM	$32	

Approximate Price: $1,832 or $2,732

IT'S HAPPENING: The scalpers are eating each other; prices are falling. Our system builds are dropping in price across the board, too, despite us throwing various upgrades at them. The Radeon RX 6900 XT is down by $100 compared to last month, and the RTX 3080 is down by $50 to the low, low price of $2,250. Yikes! But, hey, it's a start. We are also hearing mutterings of the RTX 3080 Ti making its way to our shores soon, and this thing has a combination of hardware and software workarounds that should block performance from cryptomining. We'll wait and see how that pans out, but if true, it should alleviate some of the pressure on the market, and provide us with a semi-tolerably priced card to pop in our turbo builds.

THIS MONTH'S STREET PRICES

Outside of that, the biggest movement we saw this month was in the price of those premium 360mm AIO coolers for something more down to earth. For the AMD build, we've gone with a sleek little EK number, the EK-AIO Basic; despite the odd naming scheme, it's a subtle black design that is almost identical to the EK-RGB variant we're using in this issue's build. It's also $60 cheaper than the RGB model. For our Intel system, we've gone with the Be Quiet! Pure Loop 360mm, which is basically the same cooler we used last issue in our VR ITX machine, but with that much bigger rad.

For our AMD system, we've also upgraded our motherboard and storage combo to something more modern. The Sabrent 4 Plus is one of our favorite SSDs from the last year, and tops the charts at nearly 7,500Mb/s on sequential reads. For our Intel build, we can't recommend the Core i9-11900K just yet—yes, single-core performance is higher, but losing those extra two cores and four threads doesn't make it a compelling sell compared to the 10-core, 20-threaded 10900K, at least, not in multithreaded applications.

If you absolutely must have PCIe 4.0 speeds, and can't wait for the 12th gen of chips to launch later this year, we recommend picking up the 11700K we suggested in the previous build, as that should cover things and save some cash compared to the 11900K, which you can put toward the 10nm chips launching later this year, hopefully.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$140	
PSU	750W Phanteks AMP 750 W 80+ Gold	$110	
Mobo	ASRock X570 Steel Legend Wi-Fi AX **NEW**	$190	
CPU	AMD Ryzen 7 5800X	$440	
Cooler	EK EK-AIO Basic 360mm **NEW**	$190	
GPU	Nvidia GeForce RTX 3080 10GB **NO STOCK**	$700	$2,250
RAM	32GB (2x 16GB) Team T-FORCE DARK Za DDR4 @ 3,600MHz	$160	
SSD	1TB Sabrent Rocket 4 Plus M.2 PCIe 4.0 **NEW**	$200	
HDD	6TB Western Digital Blue	$124	
OS	Windows 10 Home 64-bit OEM	$32	
Approximate Price:		**$2,286 or $3,836**	

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$140	
PSU	750W Seasonic Focus Plus Gold 80+ Gold	$127	
Mobo	Gigabyte Z590 AORUS ELITE **NEW**	$220	
CPU	Intel Core i9-10900K	$440	
Cooler	Be Quiet! Pure Loop 360mm **NEW**	$120	
GPU	AMD Radeon RX 6900 XT 16GB **NO STOCK**	$999	$2,200
RAM	32GB (2x 16GB) G.Skill Trident Z Neo RGB DDR4 @ 3,600MHz **NEW**	$185	
SSD	1TB Corsair MP400 M.2 PCIe 3.0	$115	
HDD	6TB Western Digital Blue	$124	
OS	Windows 10 Home 64-bit OEM	$32	
Approximate Price:		**$2,502 or $3,703**	

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